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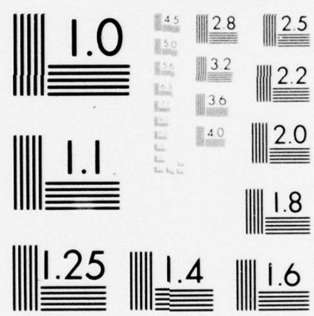

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RADC-TR-77-36
Phase Report
May 1977

SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT

Georgia Institute of Technology

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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19 REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 18 RADC-TR-77-36	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: 9	
4. TITLE (and Subtitle): 6 SYSTEM PERFORMANCE ASSESSMENT AND CONTROL CONCEPT.	5. TYPE OF REPORT & PERIOD COVERED: Phase Report
	6. PERFORMING ORG. REPORT NUMBER: N/A
7. AUTHOR(s): 10 Robert L. Feik	8. CONTRACT OR GRANT NUMBER(s): 15 F30602-72-C-0409
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Georgia Institute of Technology, Atlanta GA 30332	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 95670003
11. CONTROLLING OFFICE NAME AND ADDRESS: Rome Air Development Center (RBC), Griffiss AFB NY 13441	12. REPORT DATE: 11 May 1977
	13. NUMBER OF PAGES: 100
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Same 12 109p.	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Jacob Scherer (RBC)

ACCESSION for

NTIS White Section
DDC Buff Section
UNANNOUNCED
JUSTIFICATION........
BY........
DISTRIBUTION/AVAILABILITY CODES
Dist. AVAIL. and/or SPECIAL
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electromagnetic Compatibility
Communications Systems
Performance Monitor
Technical Control
Defense Communications System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The SYPAC report is the result of nine years of research on system performance assessment and control, buttressed by field measurements, operational evaluations, and special studies. The resultant output is a System Performance Assessment and Control (SYPAC) concept suitable for implementation in the Defense Communications System (DCS).

Specific examples of the problems faced in a wide flung communication systems

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such as the DCS are given along with some of the procedures to identify, isolate, and quantize the difficulty.

The use of Automated Tech Control (ATEC) hardware is demonstrated to portray the capability offered by an automated sensing assembly and selected printouts are provided to clarify these examples.

The rationale is given for the approach selected and the impact is presented on the operational, organizational, analysis, software, hardware, and orderwire activities of the Air Force and DOD.

The SYPAC concept is a communication system control approach where the control mechanism derives its instructions from processed data based upon performance assessments:

a) Of a few selected parameters that represent the integrated performance of a large number of devices.

b) At convenient central concentration points that also minimize maintenance and operational personnel.

c) With minimum required automated assessment instrumentation.

d) Conducted in-service.

e) That are non-interfering to customers.

f) Followed by automated assessment, data reduction, analysis, and reporting including lateral and vertical orderwires.

g) Resulting in appropriate controls exercised through control mechanisms and downward orderwires to impose any needed adjustments or restructuring.

The SYPAC report (and this Executive Summary) is written in nonscientific terms so that high level managers as well as working level programmers and staff agencies can quickly grasp the approach and intent. Thus it can be used as a general policy guide to management and staff action at all levels. Certain portions may be overly detailed for those people who have in-depth knowledge of the Air Force or the DCA Performance Assessment Programs, but in general it is written for all people who operate, manage, or maintain the DCS or equivalent tactical communications.

PREFACE

This effort was conducted by Mr. R.L. Feik in association with Georgia Institute of Technology under the sponsorship of the Rome Air Development Center Post-Doctoral Program for Air Force Communications Service. Mr. T. Yium of the Operations Research Analysis Office of Headquarters Air Force Communications Service was the task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U.S. Air Force Academy (Department of Electrical Engineering) Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

The Post-Doctoral Program provides an opportunity for faculty at participating universities to spend up to one year full time on exploratory development and problem-solving efforts with the post-doctorals splitting their time between the customer location and their educational institutions. The program is totally customer-funded with current projects being undertaken for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division

(ESD), Air Force Avionics Laboratory (AFAL), Foreign Technology Division (FTD), Air Force Weapons Laboratory (AFWL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), Hq USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), and Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC/RBC, Griffiss AFB, NY, 13441, telephone Autovon 587-2543, Commercial (315) 330-2543.

The author wishes to thank the many officers, airmen, and civilians of Air Force Communications Service who have assisted in performing the assessments and network evaluations needed to develop and prove the System Performance Assessment and Control Concept. Special recognition must go to Capt. Jacques Lemelin and CMSgt. Russell Miller for their special system testing efforts with the ATEC hardware at Croughton, England. The author wishes to thank Mr. T. Yium of Air Force Communications Service for his in-depth and continuing support and suggestions all through this effort.

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I. Introduction

In 1967 AFCS (Operations Research Report 5-ORR-67) identified that the then existing "Management concepts and techniques, and equipment for control of networks and systems, evaluation of performance, and analysis of services, have not kept pace with all other system implementation actions... tech control as conceived (at that time) fails to accomplish (its) primary role ... and fails to provide continuous real time system optimization." This report described a concept for Semi-Automating Tech Control for Communication Facilities (SATEC). The three services agreed on this concept and DCA assumed management of an overall development program toward SATEC goals. The hardware from this development effort (acronymed ATEC - Automated Tech Control) is now in field test in Europe.

The SATEC concept was further developed and refined by the author to incorporate the results of a number of special studies and characterization efforts including Scope Creek for the transmission media and Joint Autosevocom Evaluation Program for the Autosevocom network and others. Encompassed in these assessment measurements was much broadly applicable information concerning total system issues. AFCS examined the data from these programs to perceive principles and concepts that could be applied to improve field operations. There were a number of classes of ideas derived that provided significant gains to the customers, the operations and maintenance agencies, and the DCA. Many of these ideas were implemented within AFCS and some notable examples have been accepted and applied by

DCA for all three services. Some of the better known programs include the Link Assessment Program (LAP) now called Performance Monitoring Program (PMP) by DCA, the Autosevcom Network Assessment Program and the Tracals Evaluation Program.

The various assessment efforts have also provided much additional refinement to the conceptual grasp of customer service assessment and control. By 1974 much data had not only been assembled and analyzed from results of these evaluations and assessments, but also there had been considerable opportunity to evaluate, to exercise, and to experiment with the hardware implementation of ATEC as installed in England for field tests. This accumulated data and experience was analyzed to form the substantive foundation for the sequel to SATEC. This advanced concept, called System Performance Assessment and Control (SYPAC), considers in greater detail than did SATEC the customer service - the network - aspects of the system. It further addresses the noncomitant and requisite actions needed to assure control of the entire system.

Therefore, the SYPAC concept is intended to be that coherent, integrated approach to Communications System Performance Assessment and Control suitable for use in the DCS.

ATEC has been referenced numerous places in this study. The ATEC measurements portrayed are the actual assessments and printouts as presently provided by the hardware. ATEC is in theory, and also in real life, the first partial implementation of the SYPAC concept. The ATEC concept was designed so that the bulk of the assessment and control activity could be accomplished by a digital computer and software. This approach was selected because of its flexibility. A processor can be replaced by another with faster processing speed or bigger memory. Processing can be either centralized or decentralized, and of course the computer software can be modified, converted, expanded or new elements added at will, but the basic structure remains. SYPAC retains the same approach.

Starting in 1974, the AFCS testing of ATEC in the field changed from the box by box approach pursued as required under the development contract to a basically system-oriented testing predominantly conducted by personnel at HQ AFCS and the Croughton Comm Group in England. These thin line system tests conducted in depth have covered much much more than simple backbone structure assessments and have demonstrated applicability to the networks and to the entire system.

AFCS ATEC system testing, in addition to viewing the backbone radio links, also assessed the tail paths to the base manual private branch exchange (PBX) and later to selected customers within the base plant. It was straight-forward to measure the idle channel noise and other selected parameters that indicated the condition of the base cable plant and the base communication structure as a whole.

In order to form a better basis for the SYPAC total system performance assessment and control concept, many network/system tests were conducted. ATEC was able to detect and assess many problems in the four networks addressed -- the AUTODIN network, the AUTOVON network, the weather dissemination network, and a dedicated voice network. Again, these problems were detected in-service with no awareness of faults by the tech controls or management structure. A point of great interest, from a system control standpoint is the ease with which the automated sensing could be used to measure these network difficulties, in-service. There are many critical and salient signal signature parameters which can be sensed to assess the network performance and to predict trouble of the network and to warn as certain failure thresholds are approached in each network. A number of parameters have been identified and tested, but have not been automated into ATEC software. However, the principle of in-service monitoring of networks has been established. SYPAC was conceived for effective assessment and control of the common backbone structure, the tail links, and the air base complex, and appropriate sensing, processing and control of meaningful parameters of the dedicated and switched networks.

The original expected goal of SYPAC implementation was to be increased performance of the already installed plant and the associated cost avoidance for overbuilds; optimum performance of all new plant inserted into the structure; and increased performance and capability for networks worldwide -- resulting in operationally acceptable customer services.

A concomitant SYPAC goal added since SATEC is to reduce the number of people engaged in the total activities of operating, maintaining, and managing the communication structure. The prime savings in personnel will not come from any one facility or office. It is certainly in error to view either ATEC or SYPAC cost effectiveness solely derived from tech controller personnel reductions. The dramatically changed reporting procedures, centralize analysis, focused maintenance and command action, the capability to control an area operation from the automated reports available at higher levels, all work together to change personnel total and quality requirements, all through both the service O&M commands, and DCA.

Finally, and as an integrated result of achieving all SYPAC goals, the communication network complexes will be capable of effective restructuring in cases of stress or military action. This then can assure that the networks for command and control will survive as long as there is any significant connectivity and network hardware remaining.

The evaluation of ATEC to date has been on a Frequency Division Multiplex - Frequency Modulation (FDM-FM) and audio structure and with digital traffic introduced by modems. Soon the structure will become a mix of analog and digital equipment; however, the basic functions of ATEC will not change in the least, even when the full digital world arrives. The ATEC now has analog to digital converters to present the analog data to the computer in an appropriate digital form for manipulation. In the future, ATEC will need to add only digital to digital converters or digital to analog converters to accomodate digital equipment. The added sensors or suitable performance indicators can be an integral part of the basic digital equipment, or added to the system structure, but in any case represents a small cost. The prerequisite to conversion to any future configuration entails only identifying the proper parameters to be assessed and modifying the software to meet the needs of hybrid or digital systems.

The conclusion then is that ATEC has already demonstrated the validity of all of the major basic precepts and concepts of SYPAC, and thus has opened the way for rapid transition to a fully optimized and controlled DCS, and minimum total system cost.

II. System Control Considerations

A. Definition of System Control

All systems, including communications, are composed of subsystems and component elements with many variables and adjustments. The communication equipment hardware is a variable and is a function of the original design, the production quality control, the installation suitability, the maintenance effectiveness, the operational conditions, and the type of service demanded. The hardware is intimately interfaced with humans in many places -- obviously components with high variability. Any human involved as a maintainer or operator can degrade or disrupt a part or much of the total system. The customers themselves can disturb their own or the services of others. Thus, action is required to correct any disturbance and restore acceptable effectiveness and stability to the system.

System Control, then, is defined as the continuing adjustment of all needed elements of the total system to assure proper operation of not only all the hardware and software elements, but the total system; while constraining users the minimum amount necessary to protect the rights of all customers. A prime function of Control is to absolutely assure that higher priority users can, at necessary times, communicate as required, but at the minimum expense necessary to lower priority users.

Certainly, no control should be exercised when all is well, but, equally obviously, control must be applied when changes are needed.

Inferentially this presumes that before any control is exercised to provide the optimum performance, the status of the system to be controlled is known. The knowledge of the system status presupposes the ability to measure and quantify the key parameters descriptive of system operation. AFCS has worked for the last eight years on a broad spectrum of activity deriving, refining, and field proof testing parameters that describe system status. These studies generically are called "Performance Assessments."

The performance assessment parameters thus far selected were intended from the start to form the input data for total system control. The SYPAC report is a discussion of much of that work, and describes a SYstem Performance Assessment and Control concept based upon proven performance assessment results. One salient goal was kept in mind during the SYPAC formulation.

People are frequently fallible, and they do not integrate effectively with high speed automated control mechanisms. Thus the SYPAC concept minimized the human serial participation in all system control activities where feasible. This concomitantly reduced the number of people required to operate and maintain the system and provides associated cost savings.

B. Performance Margin

Performance margin is the term used throughout this report to denote a concept relatively new to communicators. A homey example may be useful to illustrate the performance margin notion. Suppose a new car can deliver 35 miles per gallon (mpg) when properly tuned. Later the car will degrade and the mileage may drop to perhaps 25 mpg, yet even then the car may start and run acceptably -- if the weather is mild. The performance capability has truly degraded, but may not be recognized unless miles-per-gallon records are reviewed. If the weather, however, turns cold, the car may not start even with a good battery. At the no-start point, the fact that maintenance is needed is obvious. Some people will blame the weather, but the basic problem is clearly lack of maintenance. Operational needs cannot be met, so the performance margin is zero. Had the driver of the car made assessments, he could have observed the performance degradation and acted appropriately as the mileage dropped below 35 mpg.

Let's assume that the car owner takes his car to a garage and upon completion of the repairs finds his mileage is 30 mpg. He would know that all repairs had not been made, no matter what maintainer protestation he may be given. A repair job that restores 34.5 mpg is a good one. The owner with initial performance data and good records can know exactly his performance degradation. This will permit him to manage his car and take those actions that will make his auto immune to hazards of weather extremes.

This idea of performance margin applied to a radio link is equally easy to grasp. When a radio link is designed, 10,000 times (40db) more signal is provided to the receiver than the minimum required. This excess signal is intended to permit acceptable operations when heavy rains pass through the radio path, or when temperature inversions cause the signal beam to wander off axis. Each of these effects can sporadically induce signal losses of 30 db or more. Maintenance thus can be authorized only a few db. The 40 db performance margin must be maintained even during relatively normal periods between these primarily weather-induced phenomena. Maintenance personnel often permit the adjustments to drift, the receiver to desensitize, the transmitter to lose power, and the electronic componentry to get noisy. In fact the users still get quite acceptable service, even though the radio equipment is badly degraded, often 20 to 30 db (100 to 1000 times) too noisy. This poor maintenance does not really cause operational trouble until a 30 db rain storm, or a temperature inversion arrives, and the remaining performance margin is inadequate. The 20 db equipment degradation plus the 30 db storm deterioration add arithmetically and exceed the 40 db performance margin. Since it is obvious to everyone that it is raining, the communications outage is incorrectly attributed to propagation. Yet had the maintenance been adequate, the rain would have caused only a slight drop in quality but the system would have provided acceptable service all through even the depth of the storm. It is true that "the more you work on the equipment, the better the weather gets."

Thus one of the prime elements of the SYPAC concept is to assess the performance of the system and assure that the full design performance margin is retained for use and protection during real emergencies, and not permit this margin to be frittered away by inadequate maintenance, by poor operation, or by unenlightened management. This approach preserving the performance margin, concomitantly but as a subordinate corollary, provides premium performance of the communication system. Some managers and technicians question the efficacy of keeping a system at peak performance at all time, question whether this is cost-effective, wonder what real harm comes by permitting the performance to drop 10 to 15 db -- after all the customers still have quite acceptable service -- quite like allowing a car to degrade, and then blaming the weather when the car won't start. These personnel have failed to recognize that the issue is not to keep the quality of communications at premium operation for normal periods, but rather to keep the performance margin at the link original design level so that the link performance will be at least at an acceptable level during times of environmental stress -- so that the car will start when it's cold. A requisite condition, to assure that the performance margin is retained for use during real emergencies, is the incorporation of a workable technique to measure the actual link performance level. Such performance determination is already being accomplished manually by the DCA Performance Monitoring Program (PMP) on the microwave, tropo, undersea cables, and other wide band elements although little analysis or use of the data results. Another requisite is a determination of the basic 'like new' performance standard, and criteria to decide how much degradation can be permitted before the link performance margin is threatened.

This 'like new' characterization and threshold determination is one of the desired output of the DCA Technical Evaluation Program.

The full explanation of performance assessment as applied to the wide band elements and the networks that are spread over the world is covered in detail in the SYPAC study.

C. Management

There are several schools of management. The one most widely quoted by military managers is "Management by Exception". "Management by Exception" even more than other approaches, however, requires not only sensing those critical parameters that indicate that the system to be managed is not operating correctly, but also an unfailing reporting structure, with appropriate processing and action on reported data at each level where management and corrective actions are required -- in other words, notifying management that an exception exists.

SYPAC has as its goal the full management of a communication system, including the sensing and reporting of system status and control of all critical system elements. The SYPAC goals can be summarized as providing management the answers to the questions:

Is there a problem?

Where is the problem?

Is there an adverse trend within the system?

Then, based upon this information:

Control correction of the identified problems before failure of any operational service.

Restructure the system to meet changing operational requirements.

Evaluate the effectiveness of hardware, and operation and maintenance throughout the system.

These very simple goals now are placed in a true systems context. Thus for example, "Is there a problem?" means is the performance margin degraded such that multipath, rain, heavy fog, or temperature inversion would produce unacceptable communication service. "Is there a problem" can no longer be an administrative query whether there are any customer complaints. A customer complaint means that the system has already exceeded the entire performance margin.

III. The SYPAC Conceptual Approach

A. Past

In the past, there was little technically oriented management, and even that was predominantly focused on the performance of individual electronic boxes. The assumption was placidly made that if all of the boxes operated somewhere near the Tech Order specifications, then the system, assembled from all of these boxes, must of necessity also operate acceptably. There are several basic and fatal flaws to this superficial logic. The deviations of the individual box parameters are cumulatively and appropriately integrated to destroy system operation since the box performance limits were assigned with no system framework in mind. There is also the practical impediment of assembling the information on literally millions of boxes and processing the resultant data to form a meaningful status portrayal upon which system status can be derived and appropriate actions can be made. It is immediately evident why management by exception was selected by the communications community -- there could be no other! In practice communication management has degraded to "management when forced by customer complaint" or by hardware failure -- in technical terms, when the performance margin reaches zero.

B. SYPAC

In the future an entirely new approach will be used. The scientific foundation for this new concept is straightforward and based upon performance assessments from which performance margins can be determined.

Performance margin can be assessed on individual boxes with great precision, however, that fails to overcome the mammoth data collection, processing and analysis issues.

1. The SYPAC approach is predicated upon the concept that each box in a complex assembly need not be measured individually in order to assess the integrated performance of large portions of the structure. This point was illustrated earlier when miles per gallon was used as a general assessment of automobile health. It was not necessary to individually measure and combine by formula cylinder compression, gas burning temperature, spark intensity, timing, or the other myriad matters that affect gas mileage. The car integrates these and all relevant matters, and miles per gallon is the composite performance indication. The measurement of one or a limited number of parameters to sense a large portion of a communication structure has already been demonstrated. AFCS Link Assessment Program/ DCA Performance Monitoring Program measures but a limited few parameters yet it precisely assesses the condition of the many boxes that make up the measured radio link.

Basic studies, assessments, and Scope Creek like characterizations, lead to the selection of two major sub-elements of the total communication system.

a) The first system subdivision is the backbone structure and includes the total worldwide assembly of interconnected microwave, tropo, satellite, cable, etc. The backbone structure carries or supports all of the communication services. In some industry and trade documents the term "transmission media" is sometimes used. The two terms are only generally synonymous, because the backbone structure extends past these transmission media wideband components and includes narrowband elements such as the base cable plants. The backbone structure encompasses the user to user interconnect structure.

b) The second system subdivision capable of permitting the creation of a system control concept was formulated during the Scope Creek measurements. It became clear that when the backbone structure was acceptable and stable, it was possible to detect troubles with customer services and to detect and isolate them to the terminals, the switch, the crypto, the operational procedures, or other network element. The studies leading to the SYPAC concept proved that the analysis and characterization of the network could also start from the box level and cumulatively examine and measure larger portions until the entire structure was characterized. The reciprocal approach was also proved -- causes of changes in the parameters that described the performance of the total structure could be isolated by examining ever smaller portions of the total until the box or interface device causing the change in readings was located.

The integrated sum of these two categories of assessments gives the electronic health of the system.

2. There is another concept that is basic to the SYPAC approach. The present box by box measurement approach is obviously labor intensive and this equates to very high cost. Further it entails considerable travel to each box location and this costs time. The number of test instruments needed by each maintainer is large if the complete alignment task is to be accomplished.

The number of sets of test equipment to measure all hardware worldwide is very costly. The SYPAC approach is to accomplish the performance assessment from strategic points in the middle of the structure, where a fewer people and a limited quantity of expensive instrumentation is sufficient. The Performance Monitoring Program again is an example. Measurements made in two tech controls at the ends of a single or multi-hop radio path assess the performance of all the boxes in the link. When an involved backbone structure is considered, such as the configuration in Europe, the tech controls are located at major junction points of the radio links. Thus the performance of several paths can be accomplished by the same people, using the same instrumentation on all paths. This will tend to compensate for the cost of SYPAC.

3. There is an additional capability required to efficiently control any large mechanism. The sensing of the performance and the indications of changes in operating conditions must be while the mechanism is in actual operation under real life load. If the sensing instruments change the actual conditions or if the assessments require out-of-service measurements, then the actual performance of the mechanism is changed, and the sensed results are not completely realistic. Thus the SYPAC approach is based upon non-interfering in-service assessment. The measurements that provide link status are made in channels that are idle due to normal channel activity being absent at the moment of assessment due to normal traffic actions. Neither are other channels nor the usage of other channels disturbed.

4. Yet another principle of SYPAC is that measurements and assessments will be conducted bv automated devices with no serial human effort. The ATEC hardware, now in test in Europe, has demonstrated the capability to make accurate and rapid measurement automatically. In fact the assessment capability and flexibility is so great that its full power is not yet recognized. A concomitant feature of automated performance assessment follows directly. The automated measurements obviously are in computer language and so easily can be processed further beyond the simple portrayal of the measurement itself. This further processing includes compilation, assembly, editing, reduction, analysis and other manipulations needed for management and communication system control. The automated reporting can be tailored to fit the needs of each level of control.

5. A major consideration of SYPAC -- as in all control schemes is an often overlooked requirement for a viable communication structure to support the system controls -- a command and control network for the communication system. There must be suitable orderwires laterally throughout the working level sites and vertically to the higher headquarters to pass performance assessment information and processed data to management and control centers. There must be also the reciprocal paths from the HQ downward to carry the control instructions. Additionally, lateral voice channels must be provided among agencies that must operate, maintain, and manage elements or portions of the structure, to permit discussions on those technical matters not amenable to, or programmed into, the automated data processing structure.

Briefly, the SYPAC concept is a communication system control where the control mechanism derives its instructions from automatically processed data and human decisions based upon performance assessments:

a. of a few selected parameters that represent the integrated performance of large numbers of devices within carefully selected sub-elements,

b. at convenient central concentration points requiring minimum maintenance and operational personnel,

c. with minimum automated assessment instrumentation,

d. conducted in-service,

e. that are non-interfering to customers,

f. followed by automated assessment data reduction, analysis, and reporting, including lateral and vertical orderwires,

g. resulting in appropriate controls exercised through control mechanisms and downward orderwires to impose any needed adjustments or restructuring.

IV. Backbone Structure Assessment and Control

A. Performance Assessment

The concept of backbone performance assessment is quite straightforward. SYPAC is an automated implementation of a concept partially implemented manually in the present Performance Monitoring Program. The backbone assessment is in reality an expanded in-service Noise Power Ratio (NPR) measurement. The normal NPR test is performed out of service and includes only the radio equipment and propagation media. In contrast, the SYPAC in-service, non-interfering performance assessment measures the NPR of the radio equipment, the propagation media, the multiplex equipment and serial special pads, amplifiers, cables, jack fields, etc, -- everything that constitutes the audio to audio interconnection through backbone structure.

The SYPAC report provides, only a limited discussion of the basic backbone structure assessment approach since many skilled technicians and engineers understand the general theory and that portion of the practical manual embodiment now in the DCS as the Performance Monitoring Program. The SYPAC report however explores in some depth the ramifications of automation of the performance assessment measurements, and provides an examination of expanded and new types of measurements possible.

In the present manual PMP implementation the tech controls make a series of manual channel measurements, and manipulate the data by hand. The reduced data portrays the technical health of the path. There are seven parameters that characterize the broadband structure links -- whether single or multi-hop. These include idle channel noise, impulse noise, RF signal strength, baseband loading, signal level, phase jitter, and frequency offset. These parameters on a number of channels are sufficient to assess the status, the performance margin, and the trend of performance of the broadband path. These same parameters are also completely suitable for narrowband and base cable circuits, although measurements such as frequency offset on a cable are uninformative, they are still valid.

All of the characterization parameters listed are presently made manually using conventional test equipment. This is very time consuming and requires considerable skill and training. The results of these manually conducted measurements are often misread and improperly recorded. In-depth analysis is rare, and even routine correlation of parameters and major problem identification is unusual.

In the SYPAC era, these measurements will be made automatically in a matter of seconds. The results will be made available to the appropriate personnel in printed form. Further all data measured need not be presented routinely if it is within acceptable limits. The SYPAC printouts portray, not the individual status of a number of boxes, but the resultant integrated performance of the entire assembly. SYPAC will surface many chronic problems, as has the PMP. A matter of extreme importance, however, must be emphasized. A SYPAC path measurement may be unacceptable, from a system standpoint, even though the Tech Order specified measurements are all within prescribed limits for all boxes involved. This disagreeable fact often upsets both managers and local maintainers. It results from the loose procurement, installation, test and acceptance practices, overlayed by rather poor hardware/system engineering. These box vs. system problems have never been, and cannot be, surfaced by the existing logistic system.

Fig. 4-1 is an example of one of the ATEC type printout, showing the amount of data that can be derived in about 3 seconds. Also there is considerable supportive data in memory. Fig. 4-2 is a measurement made of an idle channel. In PMP only the idle channel noise is read. The ATEC measurement data is properly time and date tagged, referenced to the circuit assessed, with all seven indicated measurements (and there can be more) derived from the same data so that they all correlate and are internally consistent. This permits correlation of measurements made anywhere within the structure.

As will be expanded later, most of the backbone structure performance assessment will come as a direct by-product of assessments performed upon Autovon trunks or other voice networks channels. There will be no routine need for channel by channel measurements to assess a link with the concomitant requirement for periods of equipment or channel 'out of service'. The number of Autovon trunks over most paths is adequate to characterize the path.

There are many different varieties of automated measurements possible including every one presently possible using manual test equipment, plus many special assessments for which no counterpart instrumentation presently exists. This capability is based upon the derivation of many parameters using both direct measurement and also spectrum related computations based upon the fast Fourier transform. Further, the assessment data can be processed internally in the computer and presented in a number of forms to be of maximum use in performance assessment, fault isolation, or management and control activity. An example of such a processed presentation is shown on Fig. 4-2. This figure displays the ATEC printout of the noise spectrum of channel 007. The numbers in the column indicate the noise energies in each 100 Hz portion of the channel. The inked undulating line drawn by the author represents perhaps a more easily visualized display for those not familiar with ATEC. SYPAC display will present a more suitable portrayal. Note that in this unused channel, there are seven tones, four more than -60dbmØ, as indicated by the asterisk on the numerical printout.

The SYPAC report covers some of the additional performance assessment techniques possible in an automated environment.

B. Backbone Structure Control

As is obvious, all control actions must be based on assessments, measurements, or other information that portray the status of the mechanism to be controlled. The automated measurements made by SYPAC sensors, such as exemplified in Figs. 4-1 and 4-2, and the many other assessments easily accomplished, form the data base from which the needed backbone status can be derived. The algorithms used to collate, manipulate, process, or analyze the measurement data can be highly flexible. A few are being tested in Europe by ATEC now; others are being generated and more will be as the need

ATEC NUMERICAL PRINTOUT

radio day (raday)

Special noise
weighting measurement

GMT time

Circuit
Number

```
RH NC+10.8 I          223/1315   015
AV-55.3      NF+0100       WN-59.7G      FN-56.3      WF-56.9      NC+10.8 RH
```

The 50 and 100 Hz
power hum is 10.8
db larger than the
noise around it in
the channel

Idle channel noise 3KHz flat weighted

Idle channel noise C message weighted

This shows that the predominant noise in
this channel is 50 and 100 Hz power hum.

Idle channel noise average power
unweighted across the 4 KHz bandwidth.

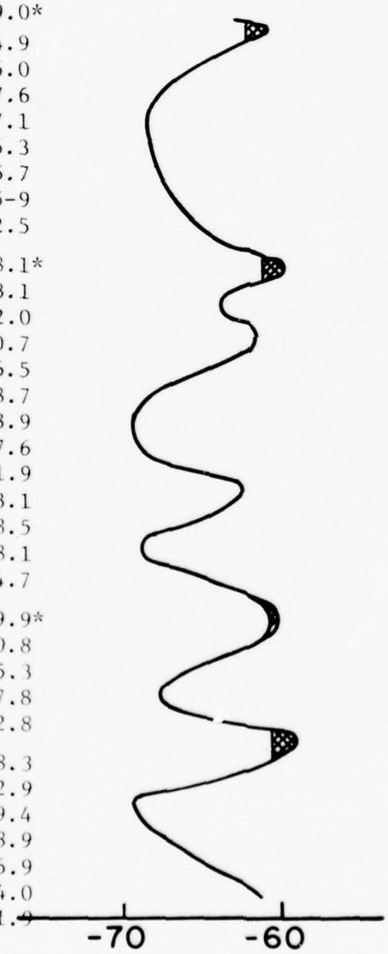
Fig. 4-1

ATEC SPECTRUM DISPLAY

```
! MI,7,2,3

C   WN-52.0 I  224/2327 007
AV-49.6      NF+0000      WN-520G     PN-48.9     WF-50.8      NC+00.0
 PI+01.4      X5-49.2
VU-49.2 PA+08.9 SW+1578 FR+0973 M5+00.8

         SPECTRUM  6----5----4----3----2----1----0----1
           01 -59.0*
           02 -64.9
           03 -66.0
           04 -67.6
           05 -67.1
           06 -66.3
           07 -65.7
           08 -65-9
           09 -62.5
           10 -58.1*
           11 -63.1
           12 -62.0
           13 -60.7
           14 -66.5
           15 -68.7
           16 -68.9
           17 -67.6
           18 -61.9
           19 -63.1
           20 -68.5
           21 -68.1
           22 -64.7
           23 -59.9*
           24 -60.8
           25 -65.3
           26 -67.8
           27 -62.8
           28 -58.3
           29 -62.9
           30 -69.4
           31 -68.9
           32 -66.9
           13 -64.0
           34 -61.9
```



Noise Contribution in each 100 hz filter

Noise in db

The cross-hatched areas correlate with asterisk printouts indicating noise, tones, or intermodulation products stronger than -60dbm∅. There are other tones that are present that fail to reach -60 dbm∅ and so fail to print the asterisk.

Fig. 4-2

HILLINGTON, ENGLAND TO MT. VIRGINE, ITALY

CHANNEL NOISE

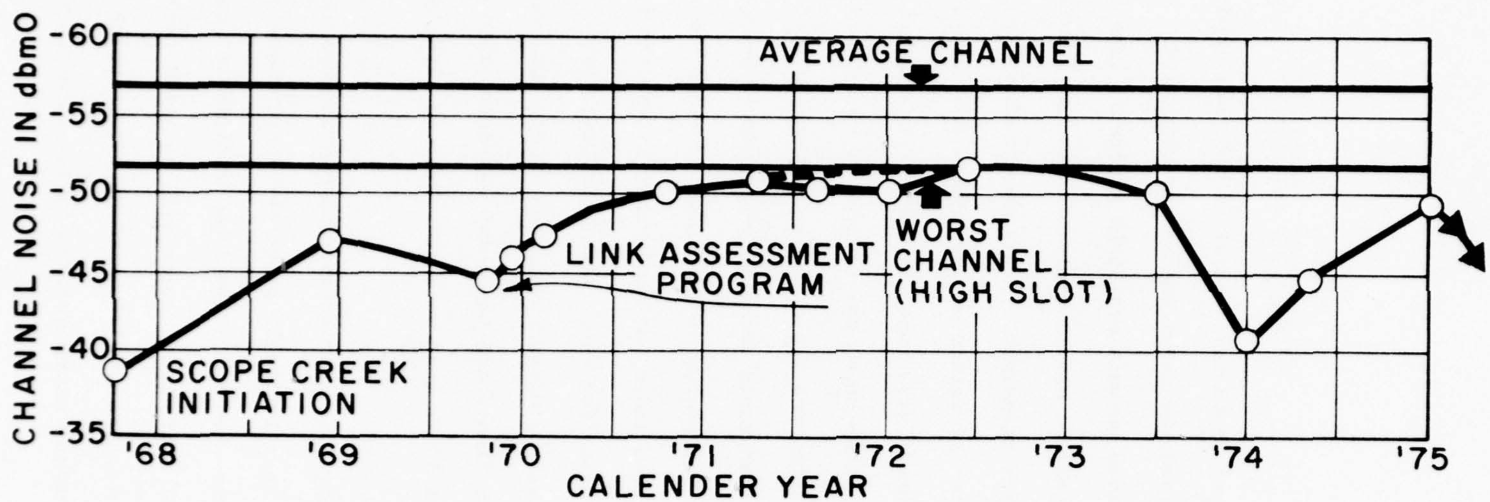


Fig. 4-3

becomes clear.

The SYPAC report discusses several of the more important considerations of data processing and the requirements for reporting. Fig. 4-3 is one of the high level derived outputs available presently from the PMP, and is based upon only a partial manual implementation of a SYPAC type backbone structure performance assessment. This figure shows the continual improvement upon the initiation of LAP (later followed by the PMP) until the existing management structure was completely disrupted in early 1974. The chart further shows the results of HQ AFCS directed special control and corrective actions, and the channel performance recovery by mid 1975, followed by a repeated rapid decay in performance precipitated by yet another major HQ reduction and change of function. Whether the management actions were the best possible under the conditions is not the point at issue. There was however clear data from which this chart was drawn. The data was used to assess the status and clearly see when special management attention was required. The data from which the chart was drawn also clearly identifies the links and multi-links that were degraded and highlighted the ineffectual management.

The SYPAC study discusses establishing standards and using the automated sensors to selectively alert the appropriate personnel and the management structure when excursion from 'acceptable' occur. The number of possible control actions of course will be based largely upon the quality and quantity of data, and the automated manner in which it can be analyzed and portrayed. Present management has little data and much of that is inaccurate and not available in proper time frame. SYPAC will permit technical managers to monitor and keep close control of idle channel noise, phase jitter, impulse noise, level and level instability, frequency offset, etc. This control can be by equipment substitution, repair, alignment, personnel changes at either the technical or management level, reduction of the communications demands (baseband loading reduction) or other appropriate action. The control can be automated in some cases, in others technical management will be required.

C. Backbone Orderwire

Most military communicators fail to view orderwires as an integrated network. They view the orderwire as one or a couple of communication channels to ease the actions needed to fix boxes at a site, or to resolve conflicts among several people trying to decide who "owns" the troubled device.

SYPAC is a system concept, and the orderwire structure needed to support this concept is much different. The orderwire must be viewed as a part of the system overhead mechanism needed to effectively control the DCS under all conditions including stress conditions. The overhead includes the performance assessment aspects and the requisite control structure to optimize the communication quality, to maximize the communication flexibility, and to minimize the personnel requirement in all phases of the maintenance and operation of the DCS. The orderwire structure is related to the DCS in much the same manner as the Command and Control networks are related to the operational combat organizations.

In the command and control world,this command network is used for:

a. Issuing orders for conduct of the operation, directing certain actions, and distributing planning data, etc;

b. Receiving status of forces, condition of facilities, and other resource data; and,

c. Reporting results of operation, difficulties encountered and requests for assistance.

In the communications world, the command and control network -- the orderwire structure -- is used for:

a. Issuing instructions on the manner of operation of the various networks or backbone structures, directing hardware reconfiguration and other network operational restructuring;

b. Receiving performance assessment status of hardware, reporting traffic status and conditions of message flow; and

c. Reporting the stresses as a result of abnormal operations, the change in network or backbone status following a centrally directed change, and forwarding requests for assistance.

This parallelism is obvious. Clearly the active command and control of the DCS (or the tactical world) is not exercised by the administrative chain threading down through the serial HQs. Thus, the conclusion is inescapable: there must be an effective command and control orderwire structure organized and implemented for the military communications system.

V. Networks Assessment and Control

A. Introduction

A communication network is an interconnection or hookup of individuals or agencies with a community of mission interest. Network assessment and control is not a new subject. There have been plays, books, television series, and numerous jokes concerning the interplay between the customer and the little old lady at her switchboard who 'managed' the first voice networks. These little old ladies were frequently slow, they made errors, they listened to the conversations, but they did develop a rapport with each other, with the customers, and with the system. Thus they provided a very effective and useful, albeit rudimentary, assessment and control, and acted as a flexible interface between the electronic portion of the network and the subscribers.

The basis of most of the management of major commercial networks now in existence is not a ubiquitous operator. The subscriber must be his own operator and assess his own service. The customer has his own ears to act as sensors and he provides his unsolicited assessment free. However, he rarely complains unless his service is nearly or entirely disrupted, so he in fact is a failure alarm. Most customers are adaptable in that they accept noise, cross talk, and spurious tones and accommodate to degraded conditions without complaint. Phone outages that occur 'after hours' normally are not even addressed for correction until the following workday. All of this seems quite reasonable to commercial telephone users.

In spite of these facts it is a surprise to most people that telephone companies, including the Bell System, never really intended to provide service 100% of the time. The goal is adequate service 95% of the time.

The telephone companies claim that to really provide 99.9% acceptable service 24 hours a day would raise the cost of phone service by more that a factor of ten. The author does not believe this. Perhaps it might be better stated by saying that it does not have to cost this much. Presently management by customer complaint is standard not only in the United States but also worldwide.

Customer complaints are not a satisfactory method to initiate military network managment. The military and certain key governmental agencies face a completely different requirement, consequently their operation must be much different. Political and military intelligence information must flow in a matter of minutes since the data is highly perishable and the information may relate to highly volatile situations. For example, if this country failed to receive notification of a ballistic missile attack and so made no command decisions or activitated no defense, the U.S. identity would be gone. Customer complaints in this context are meaningless. Thus an effective method of network performance assurance is mandatory. Yet the idea of customer complaints as 'the' network assessment sensor and the proper source of information upon which to base corrective management is so deeply engrained worldwide that most people never even question the concept. The basic engineering design of most major military networks is based upon commercially available hardware. It is inconceivable to thoughtful examination that this country and its national survival is based upon the design techniques and hardware approach developed for commercial networks whose communication goal is only a statistical 95% call completion rate -- and even that dependent upon customer complaints.

The problem is not really that the commercial world provides such poor service because much of the time the Bell System with its premium quality equipment, advance maintenance training, duplication of hardware, and with automatic or remote switching of equipment actually provides higher than 95% service but still not approaching 100%. The military do not often buy premium quality equipment. Further there is little civilian market for the technology or hardware required to provide and control a near 100% reliable system. Also the U.S. policy to foster competition among the communications firms probably will do what the policy makers apparently want -- provide a wider selection of 'cheap' service; no one, however, should believe that it will be better or more reliable. System integrity and reliablilty can only be worse and likely much degraded from that now provided. This trend will slow and probably stop what little effort there was on the development of high quality system control. Thus the military will have to go it alone in providing 99.9% service on all networks and systems of non-trivial size.

B. Generic Network

All networks have signals that traverse a backbone structure between the input and output elements. (See Fig. 5-1.) They may have common nodes such as a switch where the entered communications is sorted, manipulated, or rerouted. It is this commonality of generic features that permits a viable and reasonable solution to performance assessment and control.

SIMPLIFIED NETWORK PORTRAYAL

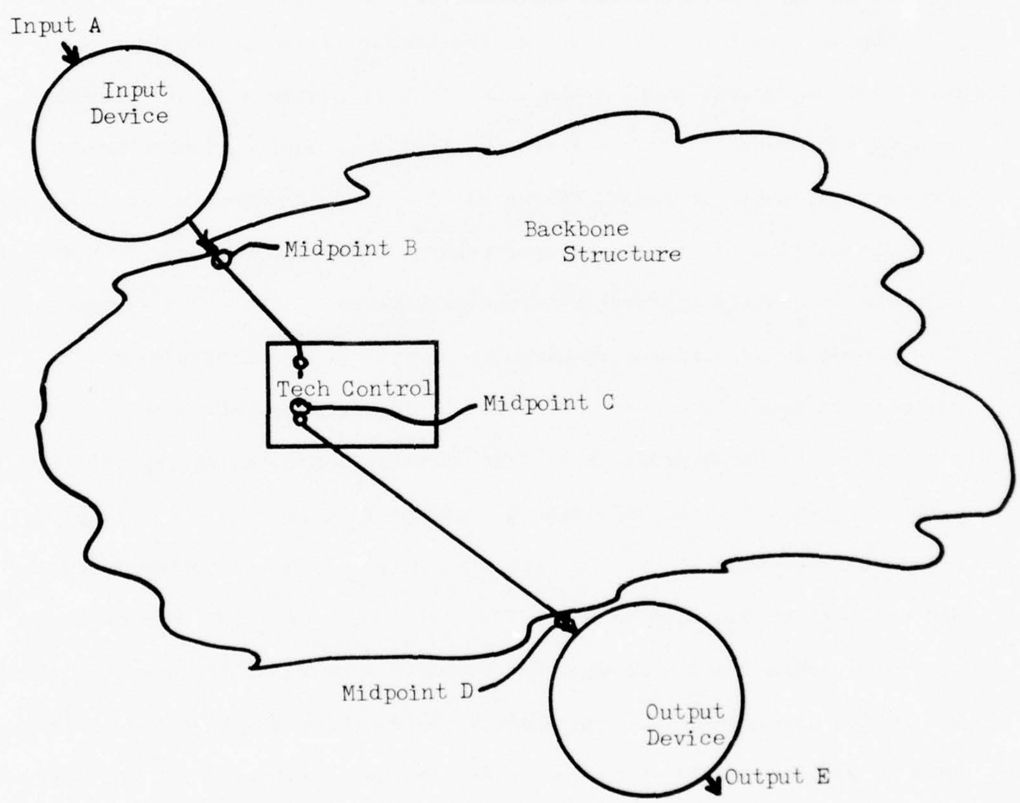


Fig. 5-1

In assessing the health of any network, there are two clearly separable functions: 1) sensing the technical health of all the elements unique to both the net and the included backbone structure; and 2) sensing the information flow and facility allocation within the network. The technical health can be perfect, but some traffic overload can ruin the network performance. Conversely, the traffic control can be perfect, but the technical problems can disrupt network operations. Both traffic and technical parameters must be acceptable if the network performance is to be acceptable.

The network hardware complex is heir to all the ills that always plague any electro-mechanical entity. There is general military recognition that the hardware associated with the backbone structure has maintenance, adjustment, and operating problems. With logic that is strange, these same people and even a large percentage of communicators somehow believe that the hardware uniquely associated with each network (although selected, procured, installed, operated and maintained under policies and procedures that are common to both the backbone structure and network portions of system) somehow works better than the hardware in the backbone structure. Every test, every measurement made in any Scope Creek type characterization, has always found the network hardware at least as degraded as the backbone portion of the network. In many cases since 1970 the network hardware has been far worse. This is not entirely due to the hardware or to the maintenance and operators, but is also directly related to the absense of total network design, poor network performance assessment (normally none), and lack of a coherent network management and control embodiment.

Obviously network hardware performance assessment must be a major if not the prime concern in network management. Certainly until the network has been brought up to the somewhat 'improved' level of performance and understanding demonstrated for the backbone structure, network technical and management attention must be heavily addressed to the hardware aspects of network operations.

C. Network Assessment

1. Signal Evaluation

Network performance assessment and control primarily is based on the demonstrated capability to characterize the network, not only individual elements, but in logical larger assemblies such as is done by the PMP for the backbone structure. This characterization is based upon the salient and measurable parameters that describe the performance of the elements in much the same way that thrust, fuel flow, pressure ratio, etc., describe the key features of a jet engine. If the fuel flow required to produce a given thrust increases, clearly degradation has occurred. This relationship can be ascertained in-service. Or put another way, all assemblies processing signals have a well defined signal modification pattern. Excess signal modification or distortion to these signals can be observed in-service as the signals traverse the communications system. Clearly measurements at the input and output of such boxes, made in-service, can ascertain whether the 'prescribed' signal modifications were observed or that excess degradation occurred. The cumulative signal distortions can be sensed anywhere from A to E -- Fig. 5-1.

In present day normal out-of-service testing activities, on almost any electronic device or assembly, the approach is to insert a test tone and then observe the distortions and degradations as the signal progresses through the assembly. There is no basic requirement that this signal be the normally used 1000 Hz tone. This tone is used because many test instruments are keyed uniquely to 1000 Hz. However once automated assessment is fielded, there is no reason to continue use of 1000 Hz or need to continue most out-of-service signal tracing. The signals already progressing through the DCS are suitable. The only requirement is that the key characteristics of the signal must be known. The Fig. 5-2 photo is an oscilloscope pattern and an ATEC printout of an Autodin good modem taken at the modem output. The oscilloscope pattern has little jitter, the line width is narrow, or as a tech controller views it, "The eye pattern is open." The parameter selected for assessment for this modem is peak-to-average ratio (PA). Note that for this good modem it is 1.0 db as shown in the PA printout. Figure 5-3 is the pattern of this modem after it has transited a portion of the backbone structure. It is obvious from the photograph that there has been considerable distortion. The original transmitted sine wave like signal had a stable amplitude while the amplitude of the distorted received signal varied irregularly and widely. The average power level of the signal printed as AV was about the same, although it is not easy to extract visually. The peak-to-average was now 5.9 db -- highly degraded. ATEC measured the degradation easily and displayed the PA results suitable for use by an individual of any technical competence level. It can easily be alarmed.

During one in-service ATEC test, an Autodin modem signal from a remote switch measured a peak-to-average of 6.0 db. Using the ATEC out-of-service capability, the fault was located. It was corrected by the maintainer while troubleshooting and without his recognizing either the

AUTODIN IN-SERVICE PRINTOUT

```
    AV-13.6 N  Ø49/15Ø3 Ø5Ø
AV-13.6     PA+Ø1.Ø     HD+ØØ.Ø     FL-22.Ø
VU-13.5     PA+Ø1.Ø     M1+ØØ.5     M5+ØØ.2     FR+1751     SW+1164
VU-13.5 PA+Ø1.Ø SW+1164 FR+1751 M5+ØØ.2

SPECTRUM 6--- 5----4----3----2----1----0----1
 Ø1 -44.3********
 Ø2 -38.6***********
 Ø3 -35.Ø*************
 Ø4 -33.5**************
 Ø5 -31.8***************
 Ø6 -29.6****************
 Ø7 -28.7****************
 Ø8 -27.6*****************
 Ø9 -27.6*****************
 1Ø -28.3****************
 11 -26.3*****************
 12 -24.8******************
 13 -25.7******************
 14 -26.8*****************
 15 -25.Ø******************
 16 -24.3******************
 17 -24.3******************
 18 -24.2******************
 19 -25.Ø******************
 2Ø -25.Ø******************
 21 -24.3******************
 22 -25.Ø******************
 23 -25.9******************
 24 -26.6*****************
 25 -26.7*****************
 26 -26.6*****************
 27 -26.7*****************
 28 -28.1****************
 29 -29.Ø****************
 3Ø -29.1****************
 31 -29.9****************
 32 -3Ø.8***************
 33 -32.3**************
 34 -35.1*************
 35 -34.9*************
 36 -35.Ø*************
 37 -37.4************
 38 -4Ø.9**********
 39 -42.Ø*********
 4Ø -43.4*********
```

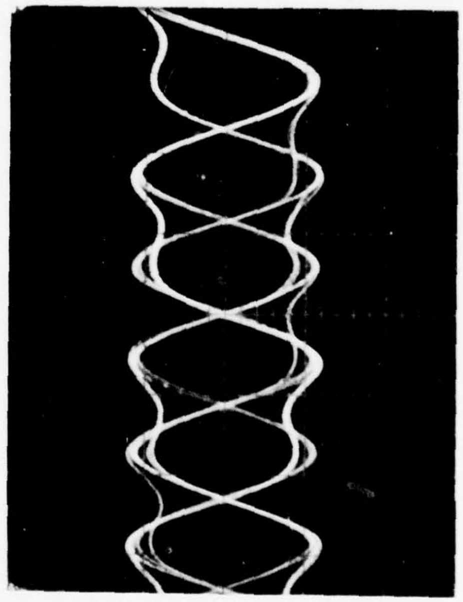


Fig. 5-2

```
MI,5Ø,2,3

   AV-13.8 N  Ø49/1531 Ø5Ø
AV-13.8     PA+Ø5.9    HD+ØØ.Ø    FL-12.6
VU-13.7     PA+Ø5.9    MI+Ø1.2    M5+ØØ.5     FR+1858     SW+1148
VU-13.7 PA+25.9 SW+1148 FR+1858 M5+ØØ.5

SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -54.7***
 Ø2 -44.4********
 Ø3 -37.8************
 Ø4 -33.9**************
 Ø5 -3Ø.1***************
 Ø6 -31.Ø***************
 Ø7 -29.9****************
 Ø8 -28.Ø*****************
 Ø9 -27.7*****************
 1Ø -27.7*****************
 11 -28.1****************
 12 -28.5****************
 13 -27.1*****************
 14 -26.Ø******************
 15 -25.2******************
 16 -24.6******************
 17 -26.1*****************
 18 -25.3******************
 19 -24.Ø*******************
 2Ø -25.6******************
 21 -24.6******************
 22 -24.6******************
 23 -25.9******************
 24 -25.5******************
 25 -26.1*****************
 26 -25.2******************
 27 -26.3*****************
 28 -28.2****************
 29 -27.6*****************
 3Ø -29.9****************
 31 -3Ø.7***************
 32 -29.6****************
 33 -3Ø.8***************
 34 -33.9**************
 35 -41.5**********
 36 -58.6*
 37 -73.Ø
 38 -78.4
 39 -79.6
 4Ø -8Ø.1
```

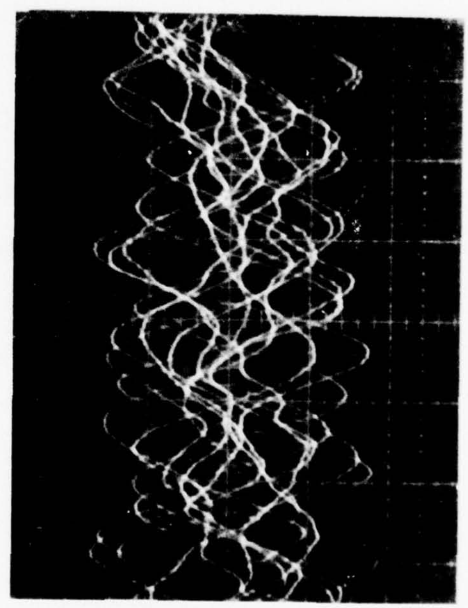


Fig. 5 3

the problem or the corrective action. He then reported "cleared while checking". This fault isolation could have been accomplished 'in-service' had ATEC been deployed at all major modes.

A series of test were run to prove that the peak-to-average reading (important for this modem) was related to modem performance margin. Regardless of the manner of stressing, the modem always failed at 7.0 db, $\pm$ 0.2 db (dropped sync.) Obviously, peak-to-average is a valid operational control parameter for this modem. The signal to noise performance of this modem is quite good, so is not normally the cause for failure but would be checked.

There are other signals whose characterization and degradation can be recognized by an automated machine or by anyone examining the spectrum plot or other key parameters. For example Figure 5-4 is the readout and spectrum plot for a new DCS modem. This modem transmits at 9600 b/s. This signature could be picked out from any other modem in the inventory very quickly by eye or by automated examination. Another spectrum example and obviously very easy to identify and measure is shown in Fig. 5-5.

2. Internal Network Signal

There are a number of special internal network signals already traversing the network that are not part of the information flow of the network. These signals are internal network warnings or directions. These messages can be detected and used to assess network conditions. For example, the particular modems that impress the Autodin signals on the

RIXON MODEM SIGNATURE

```
! MI,8,2,3

    AV-19.8 WH Ø56/1332 ØØ8
AV-19.8     PA+Ø7.1     PI-12.2     RI+Ø4.4
VU-18.8     PA+0/7.1    M1+Ø2.6     M5+ØØ.9     FR+2822     SW+1219
VU-18.8 PA+Ø7.1 SW+1219 FR+2822 M5+ØØ.9

SPECTRUM 6----5----4----3----2----1----Ø----1
 Ø1 -62.7
 Ø2 -61.4
 Ø3 -5Ø.7*****
 Ø4 -42.1*********
 Ø5 -37.5************
 Ø6 -34.2*************
 Ø7 -32.7**************
 Ø8 -33.4**************
 Ø9 -32.4**************
 1Ø -31.7***************
 11 -32.2**************
 12 -33.6**************
 13 -32.6**************
 14 -32.1**************
 15 -3Ø.8***************
 16 -29.7****************
 17 -31.4***************
 18 -31.3***************
 19 -31.7***************
 20 -31.5***************
 21 -31.1***************
 22 -32.6**************
 23 -31.Ø***************
 24 -3Ø.2***************
 25 -34.2*************
 26 -43.6*********
 27 -33.8**************
 28 -26.2*****************
 29 -29.2****************
 3Ø -49.1******
 31 -62.5
 32 -66.4
 33 -68.2
 34 -7Ø.4
```

Fig. 5-4

```
MI, 82,2,3
   AV-11.7 WL 343/1507 PART/0082
AV-11.7     PA+04.3    PI-07.4    RS+02.9
VU-11.6     PA+04.3    M1+C1.1    M5+00.5    FR+1196    SW+0983
VU-11.6 PA+04.3 SW+0983 FR-:196 M5+00.5

SPECTRUM 5----5----4----3----2----1----0----1
 01 -49.1******
 02 -51.3*****
 03 -48.3******
 04 -43.6*********
 05 -40.3**********
 06 -36.5************
 07 -34.8*************
 08 -32.5**************
 09 -30.2***************
 10 -28.2****************
 11 -21.8********************
 12 -16.9**********************
 13 -20.9********************
 14 -24.5******************
 15 -24.5******************
 16 -24.2******************
 17 -23.9*******************
 18 -23.2*******************
 19 -24.1******************
 20 -24.6******************
 21 -25.1******************
 22 -25.4******************
 23 -22.7*******************
 24 -18.2*********************
 25 -23.2*******************
 26 -28.7****************
 27 -31.5***************
 28 -33.4**************
 29 -34.8*************
 30 -35.3*************
 31 -37.7************
 32 -39.6***********
 33 -38.9***********
 34 -39.9***********
```

1200 BIT PER SECOND MODEM AT SEND LOCATION

Fig 5-5

trunks are synchronous and use an 1800 cycle tone to achieve modem set. When the network is operating normally, no such tone appears. If the network is disturbed and has to repeat blocks of information, to assure parity, periodically the modems resync and the 1800 cycle tone appears for a short time. Frequent resets are an absolute indication that "there is a problem". This reset mechanism is presently manually observable by watching the display of an oscilloscope bridged anywhere across the circuit. This existing network sensing of trouble is not used now either at the switch or the intervening tech controls. The author by observing the 1800 tone activity has predicted network failure. A telephone call to both concerned switches disclosed that neither was aware of any difficulty and neither took any action. The net failed in less the 30 minutes. Then, and only then, did fault isolation begin. It should be recognized that other parameters and signal signature degradations are sensible at any point along the path. There are many other examples to similarly buttress this SYPAC concept, including the easily detectable signature of a crypto reset since crypto reset is also a reliable indicator of network data interchange difficulties.

3. Equipment Internal Performance Assessment

Many, perhaps most, existing equipment has already available internally, often at test points, an in-service self assessment indication. For example, the self-equalizing modems such as the DCS channel packing Codex and the 9600 b/s Rixon have voltages that are a direct measure of the transmission stress between the modems. This voltage is easily brought out for network use. On these two examples the voltage triggers an alarm and gives a meter reading. In both cases much more constructive use could be made of the data -- locally, at the serving tech control, and the network control center, to initiate fault isolation, establish altroutes around problem areas, or repair or replace defective or degraded devices. There are innumerable other readily available in-service indicators such as the automic request for repeat (ARQ) signal and the 1800 Hz modem reset signal in Autodin, the Crypto reset signal, etc. All of these give an indication of some trouble or stress. Some of these indications may also be detectable at mid-points.

It is not a difficult nor expensive proposition to incorporate such features in all new equipment.

4. Network Product Evaluation

A major SYPAC proven premise derived during these network activities is that it is not necessary and is not often technically or administratively possible to evaluate the actual network product itself in assessing the condition of that product. In particular, graphic data, long narrative traffic, etc., are difficult or tedious to accurately assess and require highly skilled human analysis. It is much more informative and amenable to automation to assess critical parameters. Parameters in the DOD weatherfax network such as levels of the black and white signals, duration and level of the various synchronization and control signals, width of standard lines in a test pattern, etc., can be sensed and can be alarmed to alert personnel immediately upon amber and red threshold penetrations. These parameters have proved their usefulness in the field and are admirably suited to full automation. The basic issue is that these critical parameters can be assessed at the transmitter, the terminal, or at any midpoint in the weatherfax network to provide full assessment and control.

There are many parameters that can be used for performance assessment and ultimately for network control of Autodin for example with no need to print out the narrative traffic in clear text for evaluation. Whether the full 'good and sufficient' set is presently available is not the big issue. The salient point is that the work already performed manually or by use of ATEC has disclosed a number of 'good' parameters. More work may be needed to define 'sufficient' measurements to assure full network assessment, but there is logic and data to show that the balance of the measurements needed can be sensed from existing available or simply accessible points or from easily processed data. Recall that only 7 or 8 parameters are all that are needed to fully performance assess on FDM structure.

5. Network Assessment Portrayal

The results of network assessment have to be viewed in the total network context in order to truly 'see' how the network is performing and to put the problems in total network perspective.

Figure 5-6 shows results of a weather facsimile network presentation. The circles code the quality of the maps at the locations indicated after

EUROPEAN FACSIMILE NETWORK

(SIMPLIFIED)

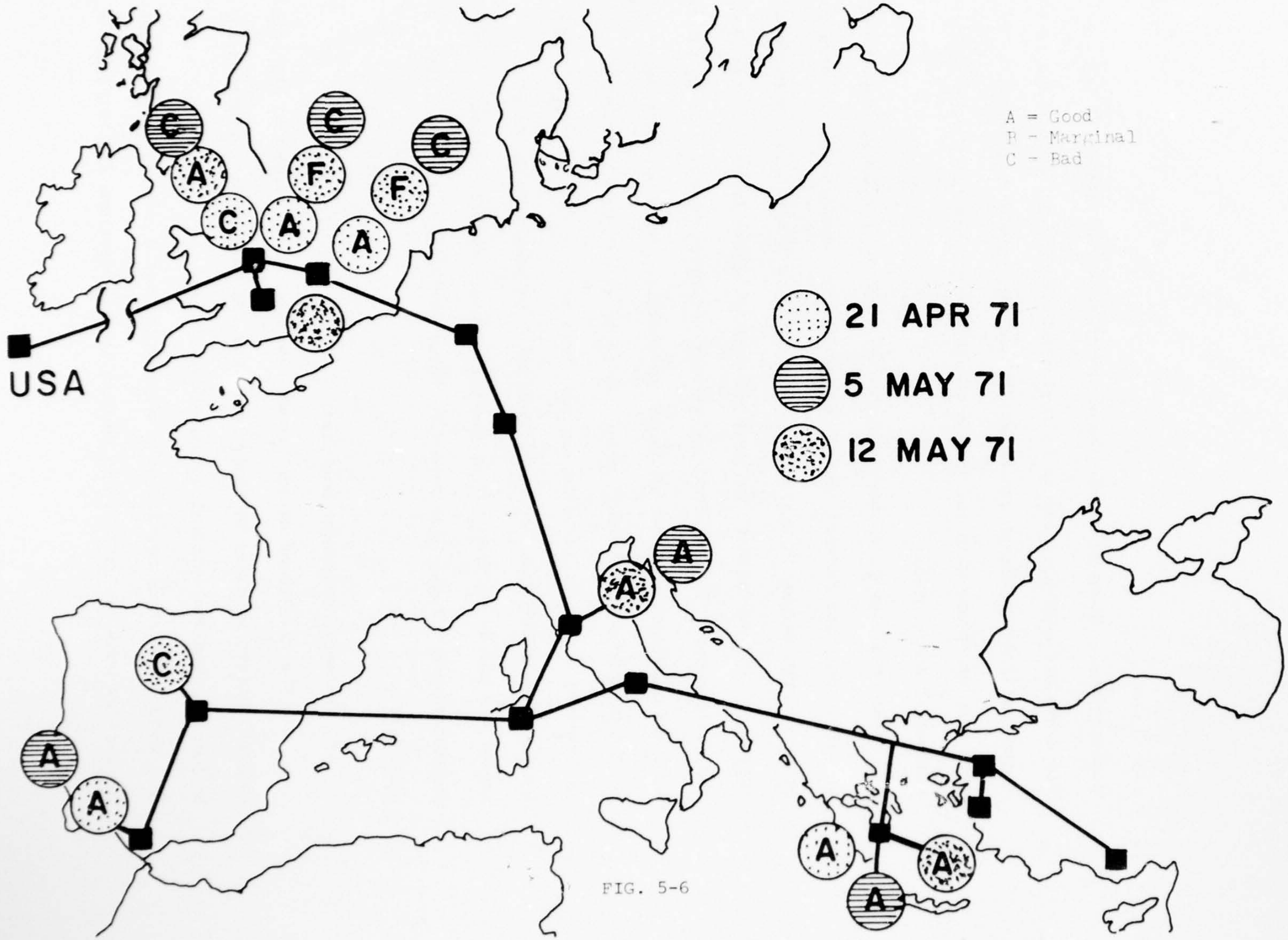


FIG. 5-6

a central HQ precise grading had been applied. A is good, C is marginal, F is bad. Without exception, all of the sites receiving maps that were graded less than A gave as the reason one of the following:

1) The backbone structure was bad.

2) The map was bad as sent.

3) The grading criteria cannot be met.

As is evident, the selected maps on these three days were sent A quality since each received a correct rating at the farthest site, yet <u>every</u> manager and technician with a less than A map blamed someone else and most blamed the backbone structure for the poor maps. The "network/portrayal" clearly showed the lack of technical adequacy and provided data-map degradation upon which management could have acted. Map degradation came predominantly 'on base' or in some peripheral device such as an amplifier or line conditioner. After a thorough examination, inadequate or non-existent terminal adjustment, poor maintenance of the supportive devices, and no management were the prime culprits. There were several ameliorating conditions that impeded effective support such as no test equipment, poor alignment instructions, etc., but the fact was clear that the basic cause of poor network performance was network hardware.

6. Stressed Evaluation

Throughout the SYPAC study, reference is made to 'stressed' testing, 'stressed' loopback assessment, 'stressed' evaluations, etc. This concept is basic. The section on the backbone structure described how the radio links were assessed audio-to-audio. Based upon the normal traffic stress loading and the measured idle channel noise and when compared with engineering standards derived when the link was optimized, the precise performance status and the performance margin of the total link can be derived.

In the network case, however, there presently is no implemented method to perform the equivalent stressed assessment. When a terminal or other network component is suspected of being degraded or during periodic maintenance activities, the terminal is removed from service and examined. There is no normal traffic processing through the device. There is no channel imposing normal noise, clicks, hums, and the device is seen in a completely abnormal condition. Fig. 5-7 portrays the obvious lack of similarity between the actual terminal use and the normally employed terminal loopback test. It is not surprising that conclusions drawn from this non-real life test are routinely in error.

Reference Fig. 5-8 -- it is clear by inspection that the stress artificially induced in the stressed loopback path is similar to real life and can be made as realistic as is desirable. The principle of this stressed test is to add appropriate calibrated stresses to the signal to ascertain if the signal to stress ratio at which the device fails or degrades to a pre-set threshold is the same as the 'like new' standard.

Envisage a device that when new could accept noise for example of -28dBmØ (with a proper signal level) before a 10^{-5} degraded bit error rate performance level resulted. At a later field test, the 10^{-5} degraded performance now results when only -35dBmØ noise is added. Clearly 7dB has been lost and the device is degraded. Corrective action is needed. The 7dB must be found

CONVENTIONAL LOOPBACK TEST -- INCONCLUSIVE

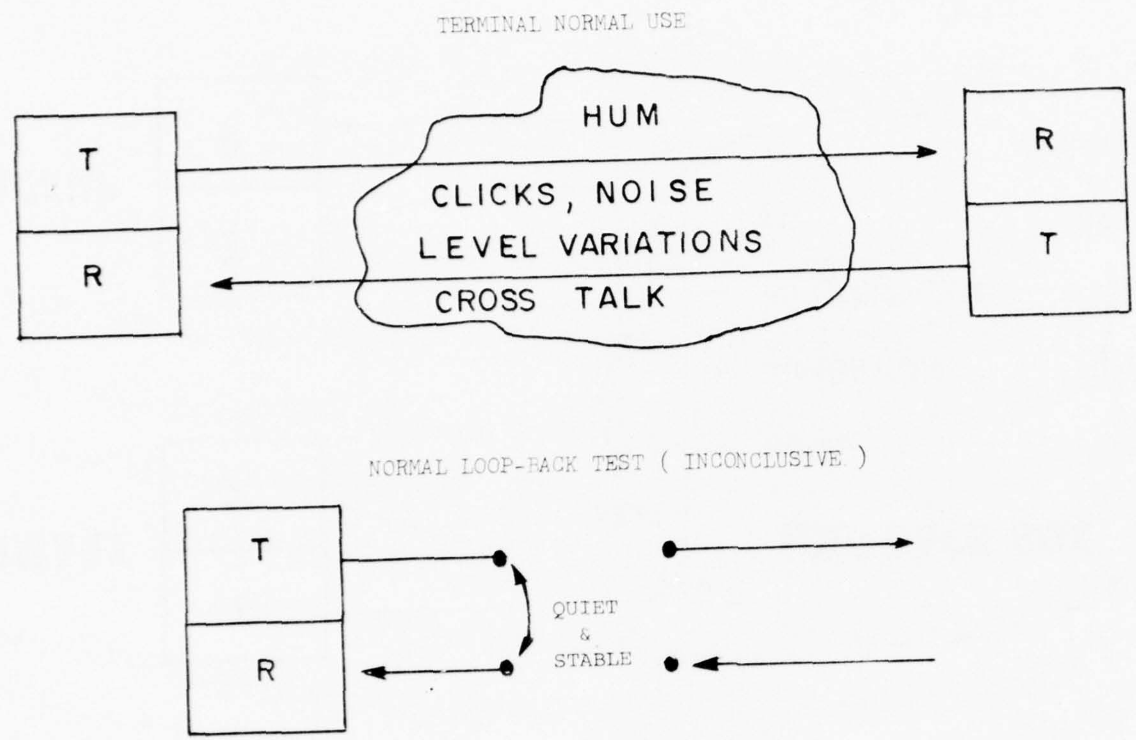


FIG. 5-7

EFFECTIVE TERMINAL LOOPBACK TEST

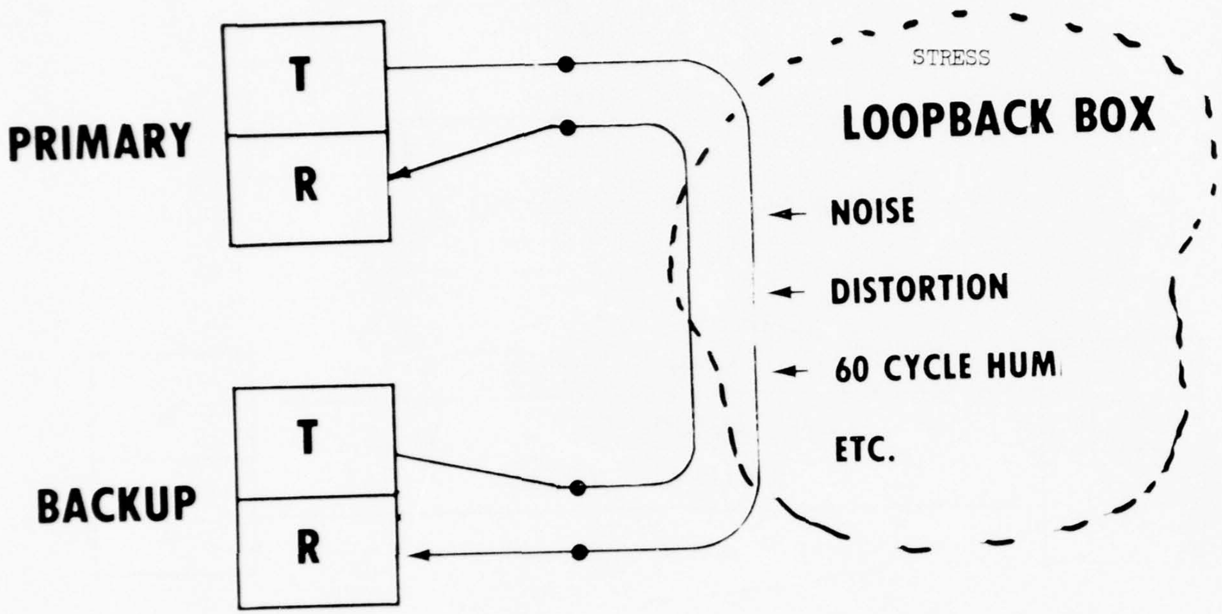


Fig. 5-8

even though the customer has not yet complained and in fact no degradation in day by day operational service may be visible to the customer.

Using straightforward techniques, stresses that increase the error rate to no more than 10^{-6} can routinely be applied in-service with no customer disturbance. Further assessment using precise and selected stresses coupled with one of the several pseudo error rate or other parametric sensors provides a rapid and excellent in-service non-interfering yet exact performance assessment with even a lower error rate.

The goal of the stressed performance assessment is not the academic one to achieve 'perfect' alignment. Rather it is required to assure that the terminals retain their performance margin and thus can be reasonably expected to function when hostilities, poor maintenance, lack of logistic support, weather, or other mishap degrade that portion of the total system, and to be sure that managers understand the true status of the network hardware.

D. Network/System Assessment

Each of the above Network Assessment concepts and approaches have been summarized in isolation. However, in the field no such one by one approach is envisioned.

For example, ATEC has demonstrated the capability to assess an Autovon trunk and by sophisticated processing techniques extract from the same sampled data most of the data needed to characterized the backbone structure carrying the trunk, and in the process discovered several types of defect SF units. The trunking arrangements in the DCS are extensive and permit not only adequate coverage to replace the PMP but also the distribution of long through groups gives adequate varying length paths to do much, and in many cases the full fault isolation down to the link and often to the site.

Figure 5-9 is an ATEC printout demonstrating this simultaneous Autovon inter-switch trunk (IST) and backbone structure assessment. The automated measurement assesses the Autovon 2600 Hz tone frequency and level, the noise characteristics of the trunk -- and concomitantly the backbone links, energy distributions, and most all of those channel parameters of interest. Further, it has been demonstrated that with precise adjustment to the 2600 Hz tone generator, the 2600 Hz tone can be used for measuring other degradations such as frequency offset, phase jitter, etc. that are needed to assess and control the backbone structure. These measurements are, of course, made easily "in-service" (no disruption of any customer service). There will be no requirement for a separate PMP program.

Figure 5-9 is the IST measurement and also the spectrum plot of this typical trunk. Both the 3 KHz and C message however have excess noise because of the presence of disturbing tones at 1300 and 1700 Hz. The predominant noise frequency is obviously the spurious tone at 1700. The ATEC instrument had no difficulty in detecting the problem and making a hard copy print out for using operator and maintainer personnel.

Figure 5-10 is a simple protrayal of approximately half of a user Autodin network interconnection. The addition of the mirror image would complete the user to user picture. Figure 5-11 is a similar visualization of Autovon. The interconnection is predominantly four wire; that is, the path in one direction is completely independent from the path in the reverse way. Thus performance assessment and control must be accomplished for both paths. The interconnection 'on base' at the users terminations is two wire after transition through a four wire/two wire hybrid for Autovon, but four wire all the way for Autodin.

The SYPAC network performance assessment approach is generally the same for these as for all networks although the details are changed.

In all networks the first step is to apply the previously described in-service signal analysis techniques to the environs of the switch node itself. The switch can be the source and also the receiver of the signal. There are normally spare input and output devices so the allocation of time sharing of the on-line processor is completely feasible with no customer disturbance created. The switch can evaluate in one direction or looped as required. This is done now occasionally by manual interconnection. The signals also must be stressed. This can be done easily in-service if an AFCS eye pattern approach [1]-- or equal [2]-- is used. The use of a Stress Box permits each box, each set of devices, to be checked with a precise numerical performance margin indicated. Degradations, completely obscure to a standard loopback, are easily detected and quantized in terms of decibels that are understood by all maintenance men. Obviously, all tests may not need to be stressed, but that capability must be available.

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(1) AFCS Project Scope Bit Phase 1 test report, Sept. 73.

(2) DCA contract with Raytheon.

AUTOVON IN-SERVICE TRUCK ASSESSMENT   CHANNEL DISTURBED

```
RH  WN-53.6 S  249/1105 008
RH  WN-51.8 S  249/1104 008 -
AV-20.1G    FR+2598G    WN-51.8RH   SN+31.7RL   WF-50.6     NF+1700
PA+02.0     PI-18.1     VU-20.0     M5+00.2     P5+00.1
VU-20.0 PA+02.0 SW+0073 FR+2598 M5+00.2

SPECTRUM 6----5----4----3----2----1----0----1
 01 -60.3
 02 -66.3
 03 -70.3
 04 -68.9
 05 -66.8
 06 -65.9
 07 -65.9
 08 -63.5
 09 -62.0
 10 -62.9
 11 -61.7
 12 -61.3
 13 -56.8**
 14 -60.5
 15 -63.7
 16 -61.8
 17 -56.2**
 18 -59.9*
 19 -66.4
 20 -66.9
 21 -67.0
 22 -68.3
 23 -68.9
 24 -62.9
 25 -25.8******************
 26 -20.1********************
 27 -26.4*****************
 28 -65.2
 29 -69.8
 30 -68.7
 31 -70.0
 32 -70.7
 33 -70.1
 34 -71.8
```

Fig. 5-9

AUTODIN NETWORK ASSESSMENT
FROM SWITCH

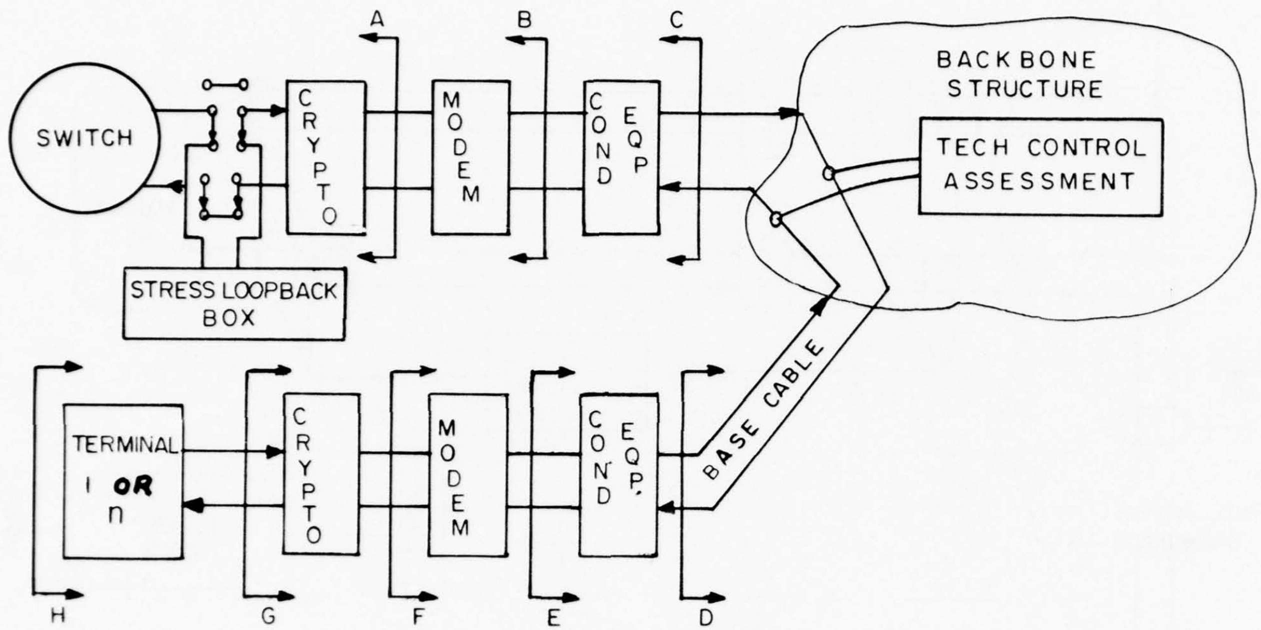

Fig 5-10

GENERIC AUTOVON

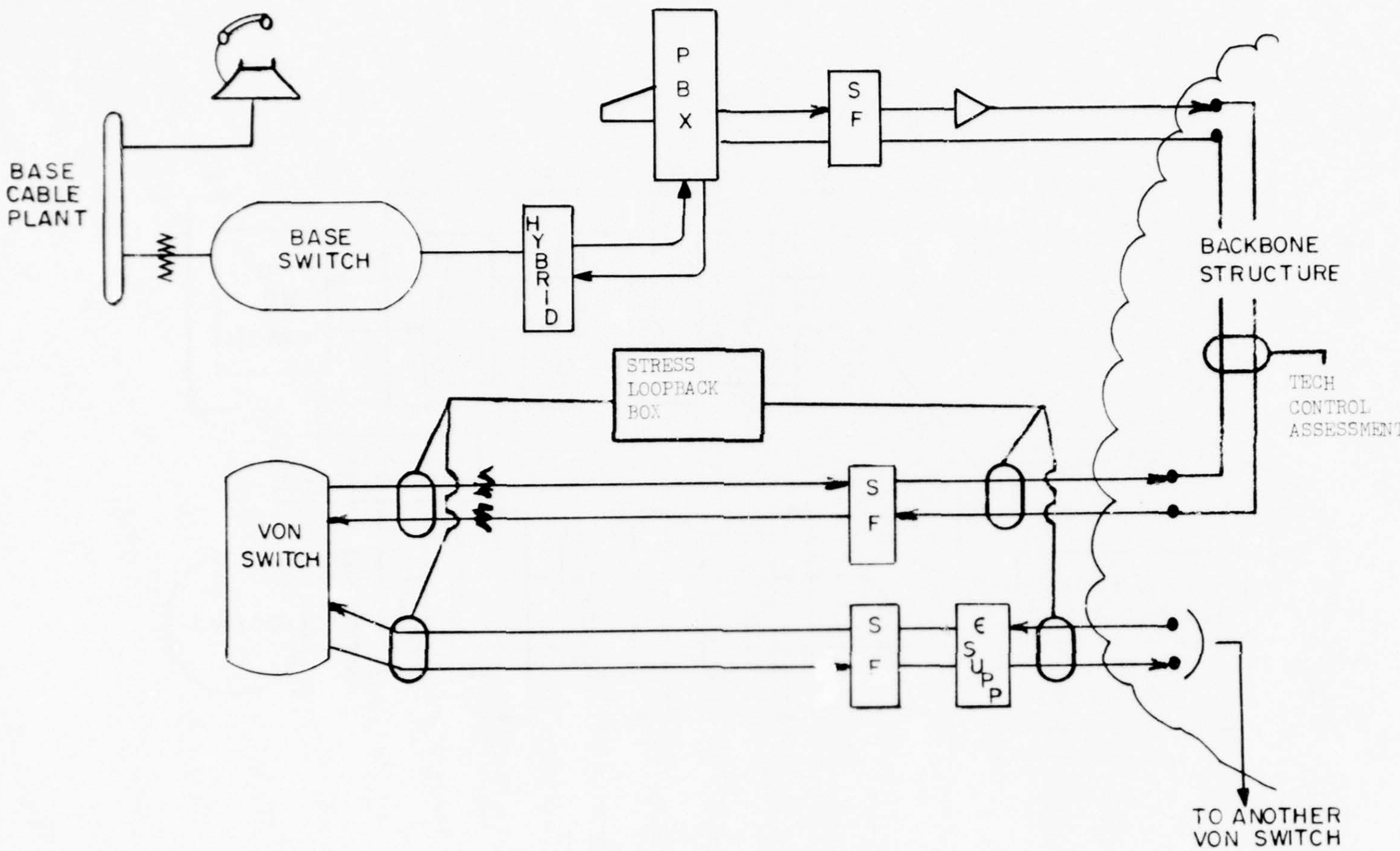

Fig. 5-11

If there are several switches in the network, each switch must be tested. The simplistic test routines now run are good, but clearly are not sufficient. In general, present routines were designed to isolate switch electronic component hard failures. There is little self test capability for assessing problems such as wave shape distortions of signals in the interswitch wiring, connectors, and mismatches at the switch interfaces with the outside world.

Once the switch is assessed (and acceptable) the next step must be to check the peripheral and interfacing devices that the switch uses to couple into the interconnecting backbone structure. The assessments must incrementally extend the scope of the assessments from the immediate switch locale ever farther until it reaches the adjacent switch throughout all interface devices at both sites. These tests must assure that the switch to switch framework is sound and that all degradations, if any, are quantitatively measured and recorded for analysis.

A prime difficulty with all networks is the poor operation of some or all of the long sequence of miscellaneous boxed, cables, converters, sensors, amplifiers, attenuators, conditioners, interface connectors, etc., that are serial on all calls. The telephone instrument itself is always serial to all Autovon network calls. It is involved not only while the conversation is underway, but is a necessary serial element for the signaling that establishes the call in the first place. Many managers will recall the false ring problem.

Tests conducted recently at several Autovon switches showed that some of all interface elements were degraded and additionally some of all interface elements were defunct. The percentage of each class of element sufficiently degraded or defective to cause trouble in network operation, at least part of the time, was high. Based upon the author's rather small sample, troublesome elements of each type would be more than 15% of the total population. A recent DCA study quoted 11% to 33%.

The figure of 15% is not restricted to interface devices at the switch sites. Tests made to local PBX's indicated that this is a reasonable number also for base functions. Thus, obviously a performance assessment approach to identify these degraded and out-of-service elements is critically needed. Taking only slight liberties with probability, any single call through four switches and associated peripheral boxes would have just a 50/50 chance of satisfactory completion because of 'minor' box degradations.

Once the switch, the switch node including all peripheral interface devices, and the interswitch trunks have been assessed, the performance assessment must next address the tail sections to the various bases. These access trunks can be approached in much the same manner as the interswitch trunks. Various one way signalling and channel assessments are possible. By use of the switch capability to call up loopbacks and easily available techniques using either loopback or special test signals the path and all the serial devices can be fully evaluated. The switch obviously will have from four to ten base structures assigned. The on base switches, hybrids, etc., will be then checked, including the base cable plants and critical end instruments for Autovon. In the Autodin network the two way cabling and the terminals will be assessed using the previously discussed techniques.

Thus the switch node is in reality in charge of a small region and is responsible for the routine performance assessment of the entire region.

In the case of Autodin, it is quite reasonable to expect that a normal switch under processor control could check each terminal frequently without causing either delays to messages in the switch and by judicious selection of a time when no traffic was either being sent or received could avoid delays to customer traffic. It is envisaged that the check of each set of terminal hardware would be to preset performance margin threshold associated with that modem and terminal type. The Stress Loopback Box would dial in the appropriate stress and a quick loopback test accomplished. No outage periods would be required since, if bit error rate (ber) were to be the critical degradation to be assessed, the stress could be quickly increased from an unstressed position until the 'stressed ber' reached one in one hundred, (10^{-5} to 10^{-7} perhaps as viewed by the subscriber).

Stressed bit error rate was used above to illustrate only, although stressed ber is certainly an excellent criteria to use as a performance assessment. As mentioned in the full SYPAC discussion, the stress can go to a 'stressed ber' in-service of one in one hundred with <u>no</u> errors evident to the customer.

E. Network Control

Effective network control presupposes a number of conditions. However, these provisos can be grouped into two general categories: a complete understanding and definition of the network designed capability and an indepth current status of the actual network performance.

The previous sections of this report have concentrated upon the matters of network performance assessment. Although not summarized separately, all discussions related to switches or terminals includes as part of the performance assessment examination and evaluation of the included network software.

The performance of the hardware and software is a prime SYPAC consideration. Policy matters, special intelligence factors, special collection structures, and military tactical and strategic matters all impact traffic control decisions and thus traffic control is not solely a SYPAC matter. It is a SYPAC matter, however, to be sure that the mechanism is incorporated in the hardware and software in DOD communications to accept any needed controls.

The network controls for each of these three elements can be summarized as follows:

1. Control the conduct, the priority, sequence scheduling, and personnel assigned for all performance assessment and fault isolation of network hardware including:

a. switch comprehensive self check

b. switch trunk checks

c. satellite base exchanges assessments

d. satellite base cable plants assessments

e. major repair, equipment substitutions, fault isolation efforts

f. switch self load assessments

2. Control the exercising and operational use of network software modification or entry including:

a. block message or call codes to selected facilities, remove communications loads from selected portions of the net for operational, exercise, or maintenance purposes.

b. block codes to prevent entry of communications that have negligible chance of completion.

c. near realtime software and route selection changes to relieve congestion, equipment malfunction or destruction.

d. a variable 'Minimize' to accept calls for delivery off same switch or off switches that can be reached over less fully loaded trunk, and can accept all calls from priority one customers and calls above some present communication threshold priority, etc.

3. Implement control of traffic by exercise of:

a. software activities covered above

b. control activation of additional trunks

c. call up satellite routes bypassing congested switches or regions

d. reconfigure the network by addition of new hardware, new RF routes, and other non-real time activities.

F. Summary

Thus it is obvious that much technical information can be used for more than one purpose. Perhaps the key overall capability provided by the SYPAC concept, however, is the switch node centered network performance assessment. The switch node has access to: all of the backbone structure assessment information to portray the status of all supportive circuitry; all of the signal evaluation to depict the electronic health of the signals accessing the switch; all of the internal network signalling transversing the communications lines to delineate those interswitch paths that are having an unusual stress; all the internal terminal/device self performance assessments to ascertain the operational quality of all subscriber terminals/ equipment; all network product evaluations to picture the subscriber product; and stressed evaluations in those cases where it is applicable and desirable. All of this information is to be presented in reduced form on a unified display at the switch node and further reduced data is to be sent to the overall network area manager. For the first time adequate data will be available -- in a highly synergistic form suitable for effective management.

In the earlier references to built-in self performance assessment, both the concepts of out-of-service and in-service were envisaged. It is not this capability controlled locally for operator and maintenance use that is basic, but rather it is this cumulative ability to assess in-service and loop back and produce quantative results that is required for remote access and control. It is this centralized assessment that really is the key to assessment and optimization and concurrently provides significant reductions in manpower needed to operate and maintain the networks.

Thus it is obvious that not only is there a viable concept for network in-service self performance assessment, but it has been largely demonstrated by ATEC, the balance reduced to practice manually and ready for SYPAC implementation.

This in-service network/system sensing information as described above combined with the hardware self performance assessment data will give sufficient knowledge to answer the key SYPAC questions:

Is there a network problem?

Where is the problem?

Is there an adverse trend?

These are the issues that must concern management, and these are the matters that must be answered before any effective management or technical control can be attempted.

VI. SYPAC Impact

A. Introduction

It is clear that as effective system performance assessment and control is provided to the DCS, it will provide the means to dramatically improve the operational effectiveness of military communications. However, to achieve the maximum benefit there must be significant alteration of the supporting and overhead structure, and a dramatic re-examination of all facets of the planning, development, procurement, operation, maintenance and management of the total communication entity.

All authors who address automation invariably promise that the phenomena automated can be done faster, better, and cheaper. However, people who automate may or may not accrue the promised gains. The failure of automation to deliver 'Utopia" is not necessarily the fault of any one group. The need for automation can only be expressed by the user and operator, and only he can be sure that all of the delivered elements are properly matched to meet his need -- it is futile to assume that the developer understands the operational need. The gains, however, are achievable only if all echelons of the communication organizations take all of the concomitant steps required to assume an integrated approach to the total effort, including organizational hardware, software, orderwires, and personnel -- total management.

B. Operational Impact

The conceptual changes discussed in SYPAC obviously will have a major effect upon all operational levels.

1. Improved Performance

The SYPAC approach was originally posed in the SATEC report as being cost effective based upon greatly improved communication capability without significant cost savings. This gain was to be achieved by reacquiring the inherent performance achievable by the plant in place. Scope Creek validated that 15 to 20 db of worldwide degradation had occurred. The PMP was formulated as a manual equivalent to SYPAC, both to demonstrate the concept and to recover some portion of the deterioration to the system. Both goals were met. The SYPAC concept clearly is viable and a 7 to 10 db improvement worldwide was documented before the Air Force management structure was decimated.

2. Manpower Savings

Technically astute personnel can readily convert performance gains as 'effectiveness' to a favorable cost effectiveness figure. Many administrative personnel, budget accountants, and unfortunately even some communication managers, are unable to grasp in depth technical gains or cost avoidance but must see cost effectiveness in pure dollar reduction terms. Further, these dollar savings frequently can only be envisioned as personnel reductions. In the case of SYPAC, major technical performance gains and also significant personnel savings are concomitantly achievable.

To achieve these gains there are technical accommodations, but more importantly, there are major and basic operational changes required, such as those to focus technical direction at the SYPAC Region framework to best achieve the technical performance, and also to reposition and reduce personnel in line with the automated SYPAC structure. The changes required throughout the organization to meet these technical and personnel goals are discussed in detail in SYPAC.

C. Organizational

SYPAC capabilities will affect every level within the command. The site squadron, node, major node, region/group, area, and HQ each have opportunities for major organizational changes that result in total command personnel savings, while achieving greatly improved technical performance.

The SYPAC report covers in detail these impacts at each level. In summary, however, the affects are:

1) Site -- The site functions will be large assessed remotely with control action centrally managed. Maintenance activities will be required, and by less skilled personnel.

2) Node -- The node is a confluence of several RF paths and is a concentration of equipment. It will be classed as a site. Since it is large it will be minimally manned. If a tech control function exists it will obviously require some controllers, but the bulk of the normal tech control activities, except patching, will be automated by SYPAC and the competence needed of the personnel can be reduced from that presently required.

3) Major Node -- The major node is the lowest organizational level where true system activities are pursued. The large tech controls, normally collocated with a switch, assume responsibilitites for major segments of the networks, works closely with the Region (DCA has recently called this a Sector) to support the backbone structure assessment and control. The total personnel assigned at a Major Node may not change greatly, but the technical competence will have to be upgraded.

4) Squadron -- The Squadron will continue to be an administrative and housekeeping organization with little direct communications mission impact. It will be viewed as a communication site, and minimally manned. Mission matters will be assessed and controlled by the Regional/Group. Flight facilities, of course, stay with the Squadron.

5) Region/Group (Sector) -- The Region/Group is the basic element in communication system assessment and control. It is responsible for a geographical segment of the total system. The assigned geographical area is large enough to provide an operational view of significance, but close enough to the activities to technically manage and control the actions. It is the lowest element that has a view of a major portion of a network and as such can be expected to assume a number of decentralized network control functions under the general control of DCA. It is the proper organizational level to assume responsibility for a number of base communication complexes since many of the present difficulties reside on the bases and derive from the lack of integration into any higher order structure and lack of system context by the base communication personnel.

The personnel technical qualifications will have to be upgraded. Technically competent officers will be required in most positions.

6) The area is being forced by recent HQ cuts into a predominantly staff support and programming function such as EurComm Area and its close support to USAFE. Technical management activity may be resurrected to some degree based upon the automated reporting and data reduction of SYPAC. Some resource reallocation across Region/Group boundaries will be possible and

broad guidance can be exercised. There is no possibility that the Area can return to its previously dominant operational and technical management role.

7) The HQ under SYPAC will have a flow of true mission status information. The actual condition of hardware throughout the command will be known and will be validated by correlative data. No longer will the command have to accept personal self-assessments and incomplete data. (Flight facilities again excepted.) The command staff then can operate on that data as desired by the commander. If the commander focuses on policy matters, the SYPAC data will provide meaningful information upon which to base meaningful formulation. If the commander chooses to play a more active role in the mission activities, again SYPAC data will form the necessary input data structure.

SYPAC capabilities will sharpen the line of demarcation between the Air Force and DCA by providing adequate information for each to accomplish his own complete task without resort to encroaching upon the other for data. The logic behind this statement is contained in the following Figures 6-1 and 6-2.

No information in any part of the system, whether related to hardware status, maintenance actions in progress, traffic flow, or trunk usage, is the sole and proprietary possession or interest of only the Air Force. The key point is that if the O&M agencies have all of the hardware components of the system 'like new' then DCA or the Specified Command need only know this in order to work on the system customer satisfaction issues. If the hardware is degraded badly in a locale, additional -- but not all --

GENERALIZED PERFORMANCE ASSESSMENT DATA FLOW
(Control follows reverse path)

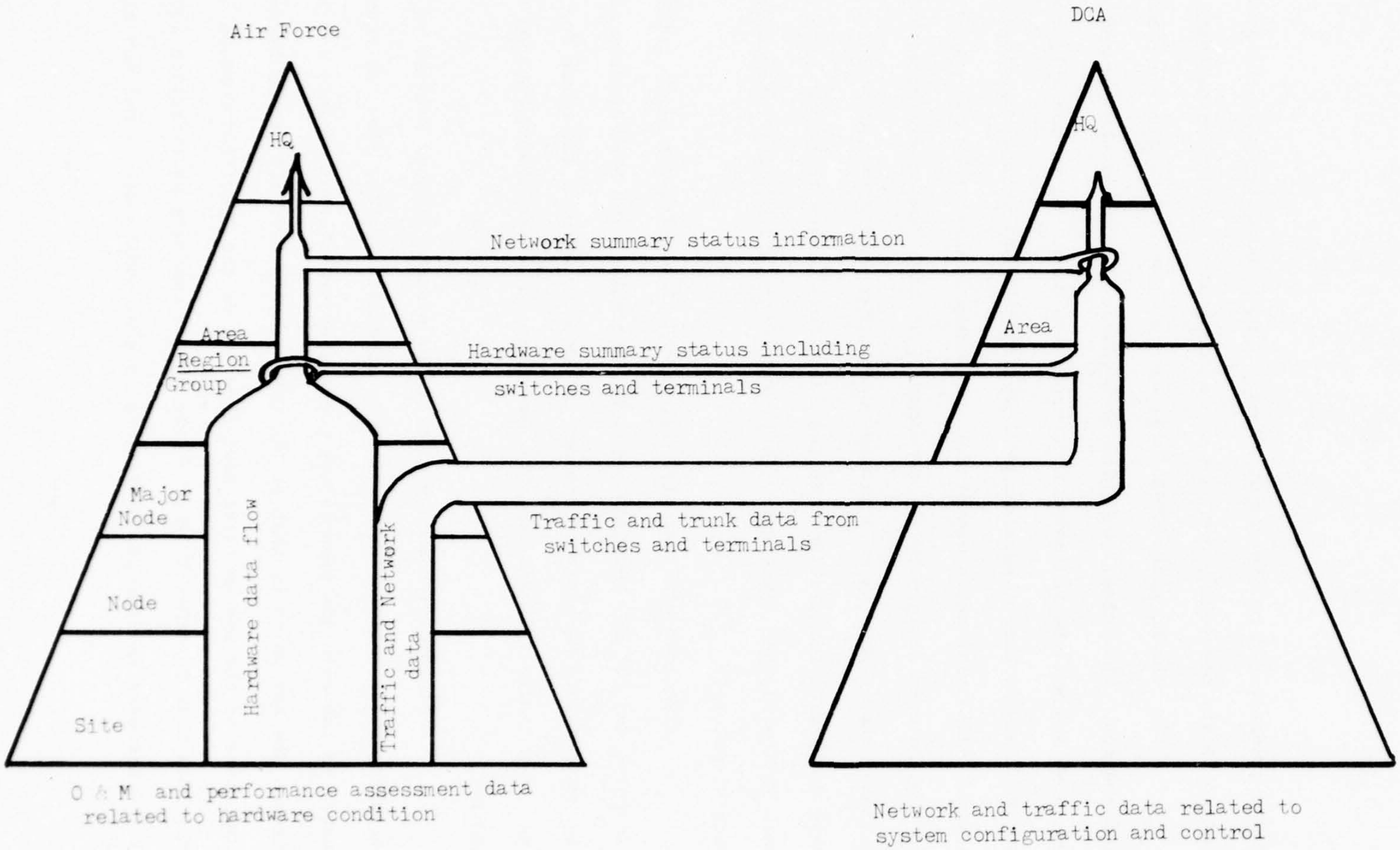

Fig. 6-1

SYSTEM RESPONSIBILITIES

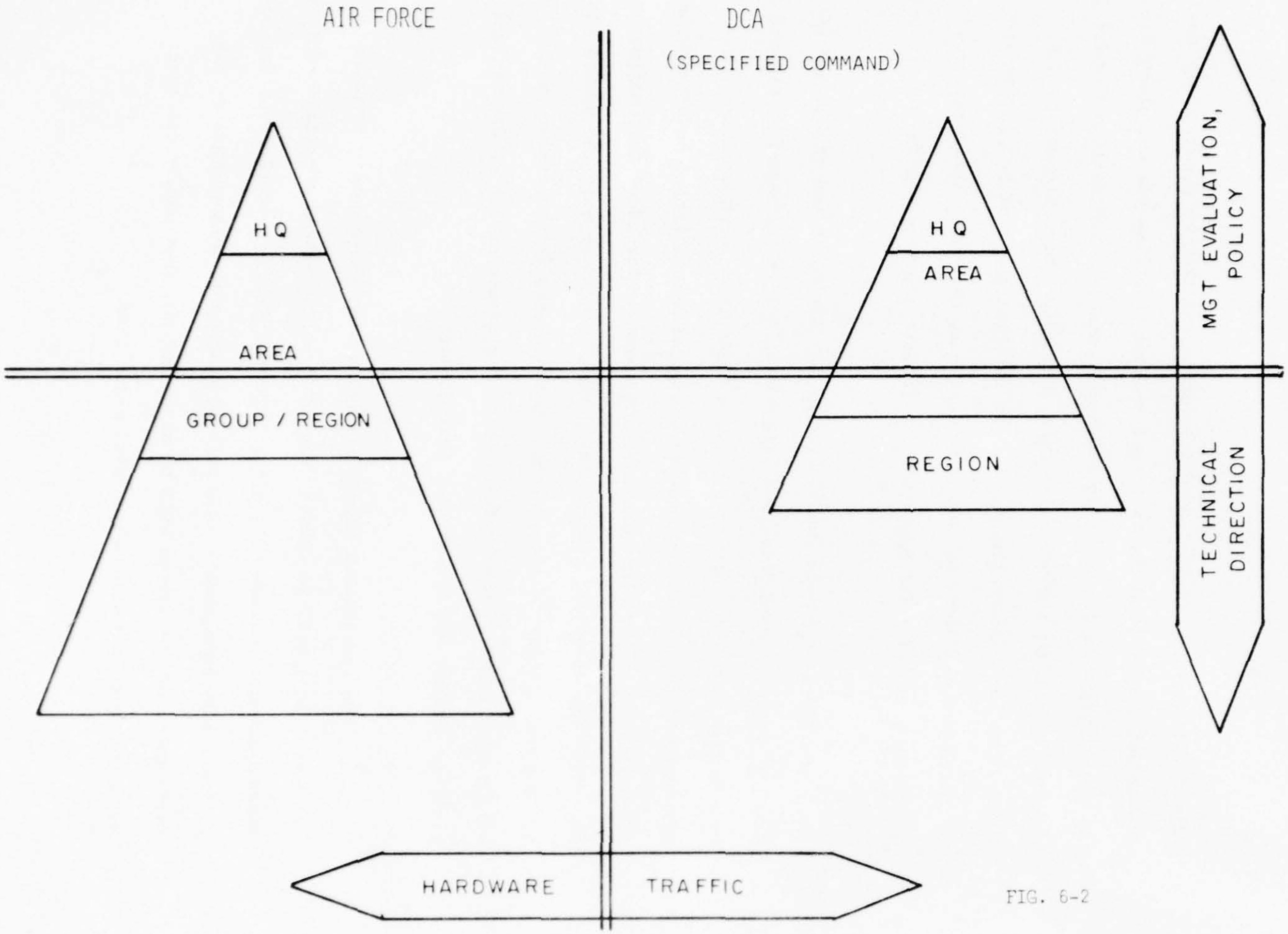

FIG. 6-2

information must be provided to DCA in order for them to pursue their goals. Conversely, if the hardware is normal -- less than like new but above marginal-- and some portion of the networks are highly stressed and failing to provide adequate subscriber service, this fact is not the sole interest to DCA. Status, but not necessarily all network information, must be provided to the Air Force or other O&M agency so that they can apply their resources to optimize hardware and operations to relieve the stressed in the affected region.

The appropriate functioning of the Air Force and of DCA and the split of proper responsibilities between the two is portrayed in Figures 6-1. This figure shows the flow of reports upward within each organization. Obviously there will be some downward communications including both technical direction and control instructions, and requests for added information or clarification of normal report data. The chart shows only the upward flow of hardware status O&M data to DCA. Not depicted in the figure is the appropriate order wire structure needed for dissemination of network and backbone control and operational instructions.

D. Analyses Impact

The operational impact resulting from the quantity of SYPAC assessment data will be large. The SYPAC software will correlate much of the sensed information, and will offer technical facts -- conclusions for consideration by management. The bulk of meaningful measurements on the performance of the system will be automated and thus easily can have automated analysis using high level algorithms.

A prime problem will be to restructure the command analysis activities to integrate the new greatly expanded SYPAC capabilities and to create a technical system management capability. The numbers of personnel at each level within the command engaged in some form of analysis must be examined. Those who are routine administrators, tabulators, and extractors can be removed with very large personnel savings and little operational impact. There will be a need for a select few but highly technically competent personnel who understand both the theory and practice of communications systems. These personnel will be the ones analyzing the SYPAC reduced data in great depth, to clearly pinpoint highly involved problem areas and to assist the staff agencies in correcting these problems. There will be some work entailed in deriving the best manner of presenting the SYPAC data to the staff and the commander.

It is likely that there will be major analysis shops at region/group, Area, and HQ with the bulk of the day-to-day analysis conducted at the region/group. It is the region/group analysis that will assist the node and major node in resolving their problems. The Area and HQ analysis will be keyed to mid and longer range analysis to assess the suitability of already implemented installations and to examine alternative methods to meet military operational plans.

The impact of SYPAC data analysis and presentation will cause considerable change to the management approach now used by both the Air Force, the other O&M agencies, and also by DCA. SYPAC will sharpen the lines of demarcation between responsibilities of the O&M agencies and DCA. It will do this by providing the appropriate data in adequate detail to permit effective fulfillment of both sets of tasks -- in hardware and traffic --

indepth current status of the actual network performance.

see Fig. 6-1 and Fig. 6-2. Presently data is predominantly related only to the O&M tasks.

It must be noted that there are two major steps between gathered data and an effective application of the data properly analyzed.

A) The first (presupposing correct analysis) is suitable presentation of the data to provide the commander a clear picture of the problem, of the framework of events or background aroung the problem, and to furnish a recommended course of action -- perhaps several for consideration -- to correct the difficulty.

B) The second is a responsive organizational structure from the decision level to the activities that must take the corrective and follow-up action. In a number of cases at the lowest levels, the corrective action will be a control signal sent to a box or terminal through the orderwire from the node, major node, or region/group. But above that level the type and structure of the management organization will be important.

The type of data presented at Area and HQ of course is dependent upon the desires of the commander. Some commanders state that they like to be current on field activities, so that they can guide mission responsiveness. Other commanders state they want to focus on policy and leave the day to day running of the command to the subordinate elements. The truth is there can be no meaningful mission guidance issued nor can there be any relevant policy generated without a deep and factual grasp of what the mission performance of the command really is. Thus regardless of the goals of the commander, SYPAC data and appropriate analysis must form the basic and mandatory foundation of any command posture. What the commander does after he understands the command posture is his decision. Action taken without the best possible understanding, however, is neither command nor management.

E. Software

Software is an area of extreme importance not only to SYPAC but to every manager in every walk of life. The area is far more critical for a communication manager than a store operator, for example. This issue is software. A manager of a store of any type has available for his own use hundreds of already developed programs covering inventory control, planning, production control, and all the support activities such as personnel, payroll, etc. The head of a department store may not understand all of the operation in his store, but he can use the predigested data fed to him by programs someone else formulated. This instant program type of management may explain why WT Grant and a number of other businesses are now facing bankruptcy -- these managers did not really understand the mission assessment data on how the data was derived and processed and did not grasp the true meaning of the computer mission status printouts and so did not make reasonable policy decisions. Since they did not understand the mission assessments, they made decisions that 'lost their war' with profits.

In the communication system area, there has not been developed a battery of 'on the shelf' programs. In the first place, the present communication system has not yet really been managed as a total system. The Air Force made significant steps forward with the genesis of the Scope Creek type measurement programs. These were characterization studies but this tabulated data could not be used by most managers. The first major program to address system performance directly and intended for the use and enlightenment of managers was the Air Force Link Assessment Program , later the PMP. This daily performance assessment measured only the backbone structure, but it did this task well. The data is available to all of the echelons within the Air Force and DCA. Yet the average staff officer and commander still has far from a full understanding of what the measurements mean, even in a gross way. The Air Force has developed several software programs for data analysis correlating the idle channel noise data with the receive signal level for example. Even though the data is highly informative, no graphical presentation of this relationship has yet received anything like staff understanding. Major field problems are not recognized so no corrective actions are directed. Clearly there is no standardization among Air Force organizations of 'off the shelf' programs that are technically acceptable, operationally useful, and understandable by an average manager.

The software for performance assessment of switched networks is still in conceptual form, but partially demonstrated manually. There has been no Air Force or other service attempt to get agreement on what portions of the network parameter sensing is desired (or needed) by the various levels of management either in DCA or the O&M agencies.

No one, however, can expect a full and complete software program for SYPAC until all the basic and prerequisite technical issues are defined and desired management information is standardized within the Air Force and DCA.

This blunt explanation is made, not to suggest that the SYPAC concept is not ready for implementation -- it is. Even with what software is known now (and a number of agencies are working on software algorithms for ATEC that are suitable for SYPAC), a great gain in system performance can result.

F. Hardware Impact

It is obvious that any time a serious attempt is to be made to restructure a large hodge-podge complex of hardware into a viable integrated structure capable of control there will be problems that require both philosophical and practical changes in the manner of doing business.

There is a record of poor performance associated with certain contractors that extends over a number of years. Perhaps the procurement people have failed to hear the rumble of discontent from the personnel who have to live with these inferior boxes, or perhaps they feel nothing can be done. But for whatever reason, there is much hardware that performs poorly during most of its operational life (although it may barely pass spec tests on the day of delivery). In the long run, this poor equipment costs five to ten times as much as slightly more expensive equipment. This is easy to understand when recalling that the life time operating and maintaining cost is approximately 10 times the procurement cost for average quality equipment. If intelligent procurement of better quality hardware could reduce the O&M cost by only 10%, the initial cost could be doubled and still retain the same life cycle costs. Studies by AFCS conducted by the author several years ago indicated that a 10% to 15% price rise could get quality hardware, could incorporate self assessment features, remote control and still save more than 50% of the O&M cost. <u>This means a net return to the government of more than five times the original purchase price</u>, and as a direct result provide much higher quality communications during its life time. It seems strange that people who play the stock market and understand 'leverage' fail to grasp the tremendous leverage available on total lifetime costs available by small increases in initial procurement costs. Yet the pressures seem to push the DOD in just the reverse direction -- minimize procurement costs and pay for this cheapening for the entire life cycle of the equipment.

G. Orderwires

There is one part of the DCS and the tactical communications structure that has been grossly malstructured. Anyone who has worked or observed the activities during the conduct of an effective performance assessment effort such as the Performance Monitoring Program or has watched competent and energetic tech controllers trying to isolate and correct a major backbone structure or network problem cannot fail to have observed the wretched state of the orderwire structure -- the literal command and control for the entire communication system.

1) Backbone Structure

It is demanding and somewhat tedious work to keep a communication site at peak efficiency, and nothing destroys the initiative, effectiveness, and capability to do the job more completely than being prevented from doing the job because of the inability to talk to the people, all the people, concerned in the action. Teletype or other data terminals do not suffice.

One of the existing conventional orderwire schemes is considered by some to be ideal. It consists of a long party line type major node to major node channel with all intervening stations connected. When someone desires to talk, he dials a number and the appropriate phone rings. If he has to work with several stations he must dial each in turn and then have them stand by while he dials the others. This orderwire has all the miserable aspects long recognized by all party line users in the commercial world.

In practice a tech controller who really needs an orderwire circuit and cannot sit and wait uses AUTOVON at "Immediate" precedence. This uses much more overhead, disrupts precedence calls, invalidates the pre-empt concept -- and in reality, does not save orderwire circuits. Clearly, the orderwire shortchange 'piper' is being paid, but at a very high cost. Any attempts to improve system control without a full support to the communication system command and control orderwire structure is guaranteed to be less than cost effective. The above discussion has discussed only the orderwire as it is being used today, predominantly for reroute and restorals of failed circuits. Effective performance assessment checks or other routine tests and control is not yet even attempted. The DCA has addressed but a small portion of the needed functions requiring an orderwire.

2) Networks

In the past, some networks have had an orderwire. On occasions switches or important users were connected to the adjacent tech control, but this was more a matter of interconnecting all collocated facilities rather than an attempt to interconnect sites having a community of interest and common responsibilities. Further, a limited number of people recognize that network functions must be coordinated and controlled if the total network was to provide acceptable service. Many people failed to recognize that the network functions were intimately and indivisably related to the backbone structure functions.

Even the commercial telephone companies have special orderwire structures for network control. These orderwires, in the case of important networks, such as network TV, do not ride the missions channels. Thus the orderwire cannot fail simultaneously with the mission network. The commercial carriers, even with only profit motivation, clearly recognize the overriding necessity to be able to talk to all concerned sites or activities simultaneously, even in the face of complete path failure. Thus the orderwire is constructed in so far as possible that both the mission and orderwire connection cannot fail together. Bell directs and controls TV soap operas and entertainment programs more effectively than DOD manages the national communication system for the survival of the nation. The blithe assumption that workable orderwires can be quickly constructed after a major link failure fails to account for realistic facts of life.

3) Overhead

The orderwire structure above has been addressed as it pertains to the backbone structure and to the networks. There is also a need for the creation of a viable communication system overhead network. It seems clear that it will be most economical, at all lower levels and probably up through relatively large geographical area HQ's, to use the same orderwire nets to sense, gather, interchange, and report data. Once this data processing hierarchy is established, little is to be gained by breaking out other reporting or interchange requirements from the basic orderwire net and re-entering in Autodin or other mission channels.

4) Control

The orderwire network to date has never been required to provide command and control to the DCS systems. The DCS must create such a control function if any realistic national emergency survival capability is to be created.

The SYPAC requirements are well stated in an earlier O&M/DCA policy authorizing four classes of voice orderwires:

a) A site orderwire from tech control to all major communication elements at that site -- switch, radio mux, etc.

b) A link orderwire between adjacent tech controls for normal channel manipulations.

c) A major node to major node wire to connect major tech controls to speed and ease the problem of major problem isolation resolution.

d) A system orderwire to connect all major nodes on an instant all available party line for rapid alert and marshalling of all elements of the system -- both backbone and network.

The radio link maintenance channel is not an orderwire and is provided for maintenance usage. These orderwires should be provided outside of normal mission hardware complement, and outside the mission bandwidth. Both of these actions are required to preclude simultaneous failure of both the mission communications and also the control structure needed to reconstruct the system.

VII. SYPAC in Conus and Commercial Service

Most of the SYPAC study discusses the overseas DCS or special installations. Under these conditions, the backbone structure and the networks are all government provided and operated and maintained by the three Services. In the overseas case, all of the system is clearly the responsibility of one DOD system manager. He has both the hardware and personnel resources assigned to do the job.

The communication problem in the continental United States and in a few selected locations overseas does not fill this singular pattern. In the U.S. none of the major backbone structure is government provided. Bell and Western Union have wide flung structures for their own use and the DOD leases circuitry as required. Bell provides the bulk of the needed connective structure with Western Union and more recently Commercial Satellite Corporation and the new limited service area digital companies furnish the balance. The government may provide the base cable plant or it too may be leased. There are bases where only the subscriber is government furnished. Attempting to manage a communication system where most of the resources are not directly controlled is obviously a far different problem than the one in the overseas areas. The more recent decisions by the FCC that permit and in fact encourage competition with Bell, yet force Bell to furnish the tail connections within the cities, has in one step made the previous management problems grow by many orders of magnitude, and has all but destroyed any possibility of real management.

Even before the proliferation a subscriber in Washington, D.C., might have to traverse a terminal leased from Company C, interconnected with the

Bell structure, go across the country and enter another telephone company structure, and then enter a base where the communication structure was government furnished and terminate on a company C terminal. This means that there are five major participants. If all works 'well' -- meaning that data can be passed with an error rate that does not cause the subscriber to complain -- no manager worries. But if there is excessive error rate or the terminals fail to synchronize or otherwise fail to provide acceptable service, the customer complains. Who is to blame? Who has to take corrective action? Who leads the fault isolation? The fault can be the subscribers who may be incorrectly operating his terminal at either end. It may be the Bell portion or the other common carrier or the base cable plant at either end. It may not be any one. Practice proves invariably that there is never a single problem. Each of the terminals are degraded, the base cable plants at both ends contribute noise, and both common carriers add their fair share of noise. Who is at fault? In many cases noise can be removed from any one of the elements and the terminals will return to acceptable operation. Remember three to four dB in a data interconnection is the difference from nearly error free operation to no operation at all. Thus each segment manager will blame another portion in what is known as finger-pointing. Each could point to himself, but does not ever do so!

There are a few locations overseas where the situation is much like that in the conus. For example, there are a number of so-called gateway stations where the overseas DCS is interconnected to the overseas common carriers. This connection is always through the local Public Telephone and Telegraph (PT&T) which is always government operated. U.S. is the only major country where the vital communication nerves of the country are in private and commercial hands -- and so far it has proved better. The problems of fault isolation in these PT&T's is more lengthy and difficult than in the conus. Getting a circuit initially brought into service is a major administrative and time-consuming episode.

These U.S. Gateway stations are responsible for services, but they control only the single tech control interconnection portion. Presently their job is impossible. Not surprisingly, the responsiveness of personnel in these facilities is poor. These personnel have learned that with the facilities at their disposal they have very little effect on the system. They quickly become purely reactive to troubles and customer complaints and route and patch around troubles. They care little about fault isolation efforts because they have no control and little influence. Nor can their bosses do more. Nevertheless, the tech controls and network managers must make or force others to make the networks play properly.

The basic concept of SYPAC as applied to gateway stations accepts the fact that other people and other agencies must accomplish the corrective maintenance actions and hardware repair and that these actions will be relatively slow and unresponsive to critical needs. Therefore, SYPAC must accomplish all the circuit and network performance assessments required to alert the carriers as soon as possible after deteriorations appear. This will not make the common carrier move more rapidly, but it will give the carrier more time for fault isolation and corrective actions prior to actual loss of customer service. Further the existance of in-service

Precise measurements will favorably move the commercial companies -- they rarely move except to customer complaints. Already, at one gateway station to Europe, the technique has worked. The overseas carrier had poor performance, but he denied it over a period of months. The gateway station made strip chart recordings on noise, signal, and other appropriate parameters. In a meeting with the Vice President of Operations, the young military engineer who had made the recordings proved his contentions. The overseas VP finally took corrective action.

The Air Force and the DCS will have to strongly pursue such a measure and complain course followed by documented speed of correction or lack of responsiveness.

This is going to be a difficult concept to sell at first both to the Air Force and to the common carriers. Most technicians, and not just service personnel, do not like to hunt for a problem while the service is still 'acceptable' to the subscriber. The routine repair approach is to fix one box and then try the network. If it now works the trouble is 'solved', even though it may fail again shortly. If it does not yet play, then another box is fixed. There is rarely, if ever, a true fix applied end to end so that all equipment is proper. The stressed self performance assessment concept described under terminals earlier in this report will give the new SYPAC approach much support. Before major problems are encountered, it is likely that the stressed threshold indicator will be flashing or otherwise recording troubles. Thus technicians now will be able to fix a box at a time, just as before, but now not to restore service, rather to put out the stressed assessment indicator (restore performance margin).

Meanwhile the customer service remains at least acceptable. Most personnel inertia can be bypassed by this approach. The occurance of customer outages will be classed as "Red", while the indications or flashing of the stressed performance meter will be classed as "Amber". The military and much of industry is conditioned to respond correctly to these two color code categories. Obviously these problems would be easier to address if the commercial world were to accept automated assessment also.

A statement was made earlier that gateway tech controls cannot performance assess the commercial backbone structure. This is true in the context of backbone management capability exercised in the overseas areas. However, in a more general way, in the sense of seeing whether the backbone structure is being managed, it can be done. The telephone companies are not happy with the approach but there is no legal impediment and no technical problem to measuring the circuit parameters on base, at the telephone, if necessary. Signal level, noise level, phase jitter, impulse voice, or any other measurement can be made at the phone interface. It is not practical to make these measurements at each telephone, but a central monitoring facility at gateway stations can work with major nodes/gateway stations overseas to monitor the condition and trend of circuit performance parameters. The gateway stations can also conduct measurements with the various communication concentrations in the States -- normally these would be bases. The history of circuit performance, the status of present capability, and the trend all can be acquired. SYPAC also can be used to monitor and performance assess those circuits in service that are used primarily or exclusively on base, such as control and voice circuits for Air Traffic Control and Navigation Aid, the circuits used between computers, between computers and their remote terminals, etc. These circuits start and stop at Air Force users so are completely accessible to measurement whether the cable plant is government owned or leased.

Thus, SYPAC will give the same general circuit and signal assessment as SYPAC does overseas. The correlation with the backbone structure inputs may not be available, but anticipation of many difficulties will still be possible.

VIII. SYPAC Digital Observations

System Performance Assessment and Control in principle is the same without regard to the type of system. Everyone who has taken courses on Controls knows the simple block diagram elements do not change no matter what device is controlled. In a control loop, there must always be devices to sense the condition to be controlled. Assuming that the sensors and the associated feedback loop including the controller are not a limiting factor in speed or bandwidth, the controller in principle can control any system. That is, an aircraft autopilot can control not only an airplane in flight, but can also be used for control of any machinery where angular displacements are to be stabilized, and a number of examples exist. There is an exact parallelism in the case of SYPAC. The basic heart of the control structure is a digital computer and its speed and capability is far more than is needed for the control of a structure as relatively slow changing as a communication system. The memory can be sized to fit the need and the software can be written to meet any requirement that can be described.

The heart of ATEC was originally conceived and produced as a ruggedized computer for control of digitally controlled machine tools, such as automatic drill presses, or milling machines. In each case the position of the drill head, or the mill cutters was sensed digitally and provided to the computer. The computer by software, guided the drill or mill through the proper sequence of drilling or cutting operations. The key of course is the sensors that detect the drill position in three axis to whatever precision is desired. The ATEC computer is widespread through industry in this application. The ATEC computer was reprogrammed to provide communication measurement and

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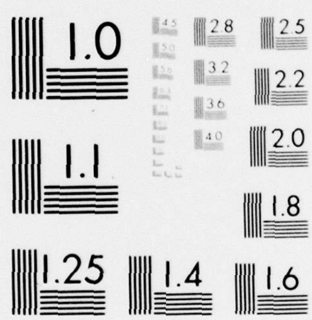

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

control. The computer still receives direct digital inputs as it did in its first application, but the DC and AC electrical signals have to be digitized prior to acceptance by the computer.

Most people refer to the communications signals traversing the tech controls of the Air Force as analog. By this they mean a special class of signals unique to FDM-FM structures. While the statement is true, it has an erroneous implication. To illustrate this point consider that the 60 Hz power that appears in every home is 60 Hz but it is also analog -- continuous. No one refers to the analog house power as though it were a special class of signal. When one has a flashlight the battery power is also analog, continuous, but everyone refers to this as DC power. All of the signals that appear in tech control are either AC or DC. Some of the signals are discontinuous AC, some are discontinuous DC, and so are not really analog except within certain time frames.

The above paragraph is not profound but is intended to show a confusion among a number of communication managers and technicians. That confusion is evidenced by the frequently voiced observation that ATEC is an analog measurement device and so is not suitable for the so-called digital environment. As was pointed out earlier, the ATEC was not originally designed for analog applications, but was designed for the digital world and has most of its relatives still working in fully digital applications. When the ATEC computer was inserted in the AC signal world, special samplers converting AC to digital format had to be provided, along with some DC to digital signal samplers. No one thought that strange. The computer was programmed independently to process the sequence of AC or DC digitized samples to give the appropriate outputs. In the so-called digital world where the voice and data terminals are digitally coded and multiplexed to form a high speed pulsating DC or square wave AC signal, the communication manager and technician believes he sees a whole new world. In fact he refers to the square wave AC signal not in hertz, but in bits per second. He sees no AC signal but only a 'digital' bit stream, yet the signal is identical with a highly limited or clipped analog sine wave, existing all through the present analog communication world. These people who confuse AC and digital signals are not really addressing technical basics, rather they are thinking in terms of the technologies that are routinely or normally used to process each class of signal. Those who have worked on FM radios will recall that the normal discriminator works from the highly limited 70 MHz IF signal -- a 70 megabit signal is processed by the receiver. Yet this is clearly an analog radio. In one receiver the analog discriminator was replaced with a high speed analog-to-digital converter and fed directly to a digital computer for processing. The 70 MHz signal was the same in both cases, only the converter changed. Thus, from a basic technology standpoint, once the decision has been made to process the data in a digital computer, the only question is to <u>select</u> appropriate parameters and to find ways to <u>sense</u> these phenomena. In the case of communications systems the phenomena include AC, DC, and clipped AC or digital signals. This sensing question is independent of FDM-FM, or TDM-FM structure. AFCS lead the effort the define and standardize the requisite FDM parameters. An identical effort will have to be pursued in the TDM structure.

ATEC presently has AC and DC-to-digital converters that sample the signals of interest and provide a digital signal to the computer. In the 'digital' world the AC, DC, and clipped AC signals will be sampled and converted to digital format for provision to the computer.

The issue then is not how will SYPAC handle the 'digital DCS'. That is a trivial question. The real question is what parameters should be measured, or what measurements truly assess the performance of the 'digital structure'.

In the case of the actual audio signals traversing the tech control, the signals are all analog regardless of whether the signal arrived over a FDM or a TDM structure, and all signal assessments are the same. The performance assessments made on an idle channel in both FDM and TDM are the same in some cases such as delay distortion and give an identical parametric feature. The measurement of idle channel noise is the same in procedure but give quite different parametric results. Idle channel noise in FDM is a measure of distortion, intermodulation, poor RF signal levels, and cable induced noise. In the TDM world idle channel noise is a measure of hardware generated noise, poor RF signal levels, lack of synchronization of the multiplex and cable induced noise. Thus channel results in FDM and TDM are basically similar but different in detail.

Digital baseband and higher order transmission measurements are quite dissimilar.

Figure 8-1 is well known to all personnel who are familiar with communication theory. The figure shows the several key features that must be understood if true system performance is to be achieved and if proper

PERFORMANCE VS DETERIORATION FDM AND PDM

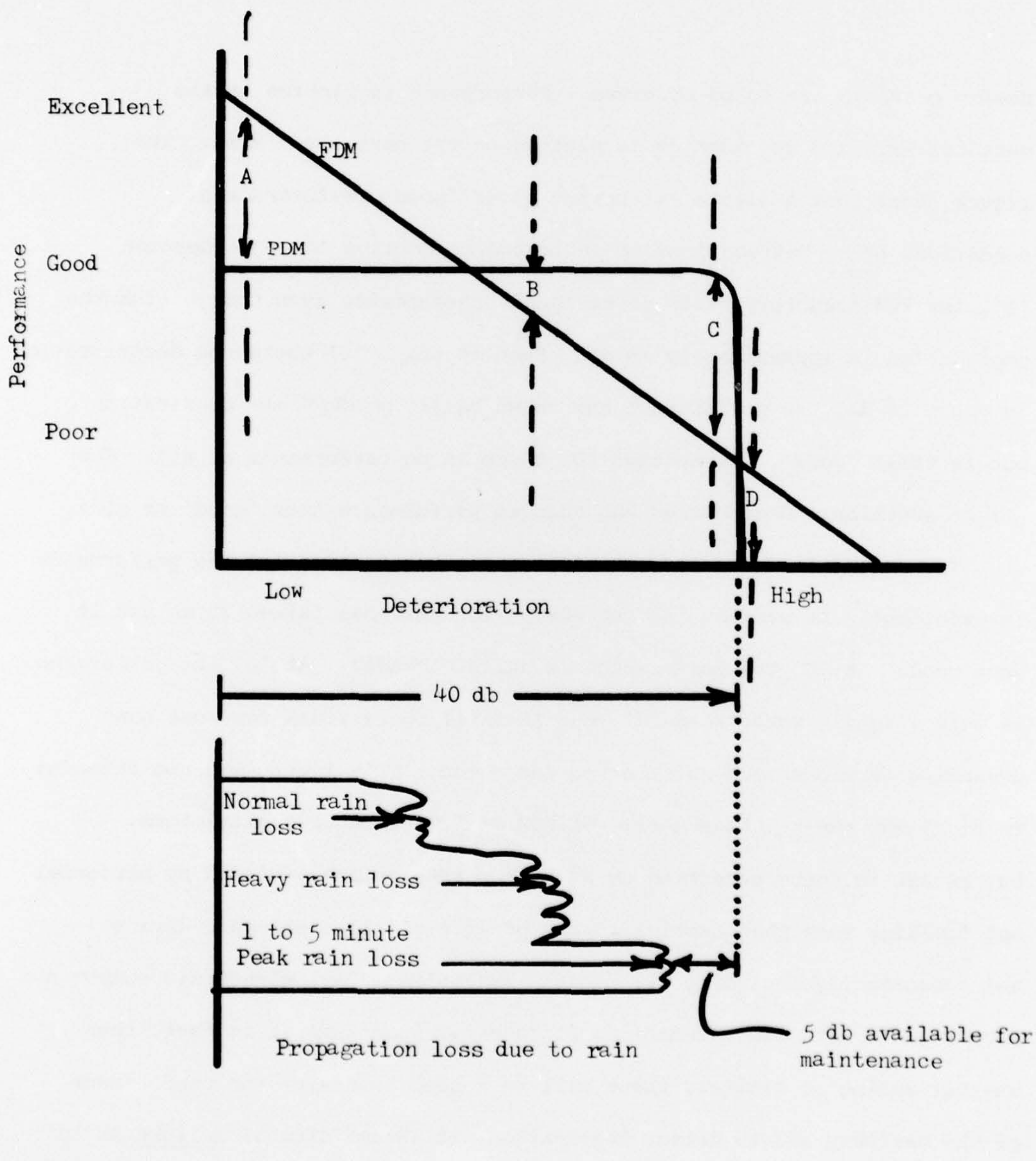

Fig. 8-1

design criteria are to be observed. Performance is plotted on the vertical axis and degradation is plotted on the horizontal axis. The figure shows that a digital structure gives 'good' performance at conditions of no degradation, as indicated at Section 'A'. At Section 'B', the PDM structure still gives 'good' performance even though link the degradation is approximately 25 db. Even at point 'C' where the deterioration is about 35 db, the performance has shown barely perceptible degradation but is still 'good'. At Section 'D' there is no performance at all. The slight additional degradation has changed performance from 'good' to none.

The FDM performance is quite different. At Section 'A' the performance is excellent. At Section 'B' the FDM performance has fallen 25 db and is just good. At 'C' the performance is quite degraded. At 'D' the performance is only slightly worse than 'C', but is still operational for some non-demanding services such as teletype and voice. This figure was not intended to highlight the relative merits of FDM vs PCM or other digital form, but rather to focus attention on a major point routinely missed by personnel not familiar with the practical facts of life of all electronic devices -- and specifically including all digital assemblies. All electronic components have a drift with time, sometimes it is slow, sometimes it is fast, thus whether analog or digital, there will be a need to assess the performance of the hardware and to detect degradation, if abrupt digital failure is to be avoided.

There is also another class of problems inherent with all digital devices and the degradations so associated are cumulative and lower the performance. When a pulse is generated in any device it is supposedly approximately square, although in reality it is distorted. This distortion is further aggravated by impedance mismatches and fortuitous circuit capacitance and inductance. The distortion sum is always significant, and quite enough to move a normal operating point toward 'B'. For example, in a large computer (a digital device) of some renown a check of the bit stream at an interface point between the central processor and a drum memory disclosed that the supposed square shape was highly distorted. When the timing was moved to the correct timing point the computer could be made to sample correctly, but the slightest jitter, extraneous noise, or minute component shift would cause an error. In this case the operating portion of the computer was at 'C' all the time and it was new.

This practical phenomenon can be applied in the same way to the backbone structure. A design performance degradation margin of about 40 db is usual on a radio link. If the digital structure associated with the link is permitted to degrade 15 dB, and this is not an unusual amount for the DCS, there is no measureable bit error rate increase as far as the customer is concerned, and this is good. This is, however, bad from a system maintenance standpoint. As a rain storm moves through the propagation path, the deterioration due to the rain is routinely 10-15 dB at 8 GHz. The above link would still play but would retain no performance margin. There are rain storms, however, that have propagation losses of 25-30 dB, and on occasions exceed 35 dB for several minutes and the link would fail. The maintainer would report the outage as 'propagation'. The real reason of course should be poor maintenance. Present day digital equipment gives the maintainer no way to test or assess his equipment except out-of-service, and the customer and maintenance detect the problems at the same time. This is unlike the FDM would.

It is clear by examination of Figure 8-1 that if 35 dB, 1 to 5 minute rain losses can be expected on occasions, and if the link has been properly designed to the standard 40 dB fade margin, that 5 dB degradation is all that can be permitted on the digital hardware. This is a reasonable number, and is the same deterioration margin standard being used in the field for FDM.

An idea was first proposed by the author and first reduced to practice by the National Security Agency, whereby for the first time a measure of predictability was achieved in digital radio link failure assessment. Later developments by the AFCS digital test bed and by the Raytheon Co. gave excellent predictive results.(1) The prediction is accomplished by a bit detection device identical to the one used in the mission radio equipment, and operated in parallel with the mission bit stream. The special detector can be stressed by adding noise, offsetting the timing or the threshold, or by introducing other suitable degradation. This stress may be imposed to any desired intensity. If the special bit detector is unstressed, the bits are produced at an identical error rate in both the mission and special detector channels. If the special detector is stressed, its bit error rate (BER) will be higher than the mission detector by an amount related to the

(1) PCS Operational Test and Evaluation of PCM/TDM Equipment, 6 Sept. 73, AFCS Project Scope Bit Report.

stress. The degree of predictability can be expressed in several ways. The one selected by AFCS is to stress the special detector and note the stressed ber, for example 10^{-2}. Then the receive signal level is attenuated until the mission bit error rate is 10^{-2}. The degree of RF attenuation required is the prediction factor in dB. The AFCS special detector has demonstrated 30 to 35 dB predictability. (1000 to 3160 times). In practice, the predictability curve is known so that it is not necessary to attenuate the signal level. The 10^{-2} stressed ber is known to be equivalent to about 10^{-22} mission stream ber and also equal to 20 dB predictability. If the original stress required to produce 10^{-2} stressed ber were to change from 20 dB to only 10 dB, it would mean that 10 dB degradation had occured. The mission channel ber would have fallen from 10^{-22} to about 10^{-12}. The change would be undetectable as far as the customer is concerned, and also unmeasurable in practice by the operator or maintainer. Nevertheless, the 10 dB system decay is real and can be easily measured by the stressed ber special detector.

However, this prediction detector is only one step. It is inserted at one point in the site, and it gives an alert when the cumulative degradation from the path and hardware passes a threshold. These effects include group delay, radio and path nonlinearities, poor RF signal strength, pulse jitter, etc. To date, however, there are few supporting measurements that can help in total system assessment fault isolation and control.

In the FDM world more than nine years work found that eight parameters were good and sufficient parameters to assess the FM-FDM backbone structure, and the interrelationship among these parameters is understood. There are additional sets of additional parameters needed to ascertain the performance of each network. The commercial TDM world in general has not yet even recognized the need for performance assessment, and little in the way of effort is underway to even investigate the problem.

The sensors that the commercial world use to control their structures are nearly restricted to the clear failure mode identifiers, such as multiplex loss of synchronization, loss of bit integrity in the bit stream as the customer sees it, or when the receive signal drops, all these are alarmed. The alarms may also be wired to switch equipment stacks, if associated with a radio or a multiplex, etc. All this minimizes the outage, but an outage there is. It may be short, it may be extended, but in any case, except the RSL induced radio stack transfer, bit integrity is lost, but then the commercial world only attempts to provide 95% overall service. The Air Force and DOD cannot expect to use the lower grade hardware than the commercial companies and these same 'alarm only' failure alerts, and achieve 99.99% service worldwide. No rhetoric, however impassioned or honestly conceived, can change these facts.

There is much work yet to be done on hardware, box, assembly, site and link performance assessment before the service reliability of a digital structure can over an extended time period match that of a well run FDM-FM structure properly sensed and managed. The key item is that the SYPAC approach is exactly at home with either and can process either data whenever the good and sufficient parameters are derived.

IX. SYPAC Implementation into the DCS

It is always unassailable logic to consider carefully the manner of accomplishment of all changes to the system. SYPAC obviously is no exception and it must be done well, but for different reasons. SYPAC will not disrupt the service. Rather, the care and sequence required in the introduction of SYPAC is to maximize the system assessment and control capability for the amount invested. This means that each step in the conversion must be well thought out, and efficiently and effectively implemented complete with the requisite hardware, software, organizational, and management changes. This means that all facets of the issue must be examined. All steps including the production funding, the installation drawings, the installation and test, the operational training, the restructuring of the O&M organization, the reformulating of the reporting hierarchy and the re-education of the O&M and DCA managers to use the SYPAC outputs. The creation of the assessment and control mechanism for the networks is completely dependent upon reflection of all of the above concepts into the necessary hardware specifications and the retrofit of existing hardware with long expected operational life, to interface with the new SYPAC framework. No one can possibly believe that the above necessary steps can be done quickly even from a purely technical standpoint. When the fiscal considerations are added, the total time becomes quite extended. The organization and management inertia, and learning and training periods further extend the time cycle.

It seems quite reasonable to spread the SYPAC implementation over at least 10 years, and it is quite likely with the pressures on the military budget, the full conversion period could take 15 years.

The first major element of SYPAC to be installed must be, of course, that element of the total SYPAC structure that automates the performance assessment functions that must be performed in and around major switch tech control nodes. SYPAC will automate much of what is now being accomplished in tech control, but the tentacles of these measurements extend much beyond tech control. Much of the manual activity and the manipulation now widespread need not be done in any well-ordered and instrumented communications environment. To emphasize -- SYPAC does not automate tech control! It does automate those measurements that should be made in the switch tech control node and many maintenance measurements. Further, many older tech controls will have to be brought up to date to permit installation of the sensing hardware.

The first installation of the performance sensing devices will be at major nodes, that is major RF link hubs collocated with switch sites. It is far more important from both the O&M and DCA standpoint to cover all switch/major nodes in an area than to saturate a small portion of the area, concentrating on all radio sites and locations. Obviously concomitantly with the first major node SYPAC installation will be construction of a viable orderwire structure to replace the poorly conceived and implemented orderwire structure, among the major nodes.

The second major step in SYPAC implementation will be the installation of the Group/Region/Facility Control Subsystem. This is the SYPAC element that starts to address system factors, and network matters in an effective matter. The orderwire -- command control -- structure must be expanded to incorporate these added inter-changes.

The third major portion is the tie together of all Group region elements and the interconnection to the Area -- both O&M and DCA. This step may not require a SATEC hardware element, but may be satisfied by interconnection to one of the existing computer directly or through an interfacing processor.

The fourth step is to fill in the voids between the major switch tech control nodes, to provide additional fault isolation information for the O&M agencies. This fourth step clearly provides the least return on the investment from a system performance and control standpoint. Added SYPAC sensors to permit unmanned sites may be more cost effective and in those cases may be elevated in priority. The first and second priorities, however, are far and away the most important steps in the first few SYPAC years.

The SYPAC final software will require a long time to develop fully. The full complement of sensing, manipulating, analyzing, reporting, etc., concepts will be an evolutionary procedure. Further, parts of the software will have to be time phased with the plant-in-place hardware development, modernization, and modification to meet the future military operational needs and to integrate into SYPAC. A broad time phased SYPAC implementation schedule is given in Fig. 9-1.

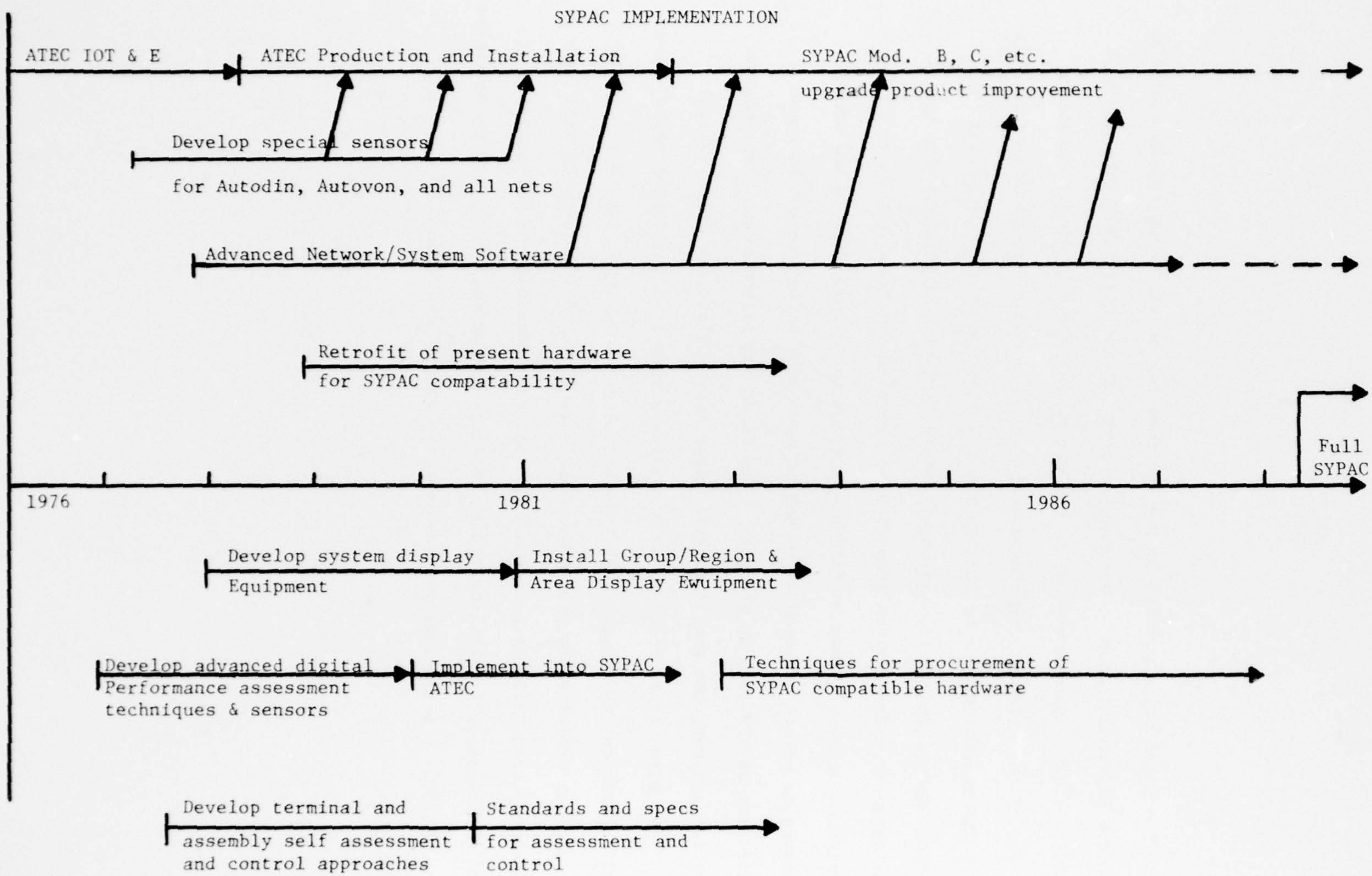
SYPAC IMPLEMENTATION
ATEC IOT & E
ATEC Production and Installation
SYPAC Mod. B, C, etc.
upgrade product improvement
Develop special sensors
for Autodin, Autovon, and all nets
Advanced Network/System Software
Retrofit of present hardware
for SYPAC compatability
Full
SYPAC
1976
1981
1986
Develop system display
Equipment
Install Group/Region &
Area Display Ewuipment
Develop advanced digital
Performance assessment
techniques & sensors
Implement into SYPAC
ATEC
Techniques for procurement of
SYPAC compatible hardware
Develop terminal and
assembly self assessment
and control approaches
Standards and specs
for assessment and
control

Fig 9-1

METRIC SYSTEM

BASE UNITS:

Quantity	Unit	SI Symbol	Formula
length	metre	m	...
mass	kilogram	kg	...
time	second	s	...
electric current	ampere	A	...
thermodynamic temperature	kelvin	K	...
amount of substance	mole	mol	...
luminous intensity	candela	cd	...

SUPPLEMENTARY UNITS:

plane angle	radian	rad	...
solid angle	steradian	sr	...

DERIVED UNITS:

Acceleration	metre per second squared	...	m/s
activity (of a radioactive source)	disintegration per second	...	(disintegration)/s
angular acceleration	radian per second squared	...	rad/s
angular velocity	radian per second	...	rad/s
area	square metre	...	m
density	kilogram per cubic metre	...	kg/m
electric capacitance	farad	F	A·s/V
electrical conductance	siemens	S	A/V
electric field strength	volt per metre	...	V/m
electric inductance	henry	H	V·s/A
electric potential difference	volt	V	W/A
electric resistance	ohm		V/A
electromotive force	volt	V	W/A
energy	joule	J	N·m
entropy	joule per kelvin	...	J/K
force	newton	N	kg·m/s
frequency	hertz	Hz	(cycle)/s
illuminance	lux	lx	lm/m
luminance	candela per square metre	...	cd/m
luminous flux	lumen	lm	cd·sr
magnetic field strength	ampere per metre	...	A/m
magnetic flux	weber	Wb	V·s
magnetic flux density	tesla	T	Wb/m
magnetomotive force	ampere	A	...
power	watt	W	J/s
pressure	pascal	Pa	N/m
quantity of electricity	coulomb	C	A·s
quantity of heat	joule	J	N·m
radiant intensity	watt per steradian	...	W/sr
specific heat	joule per kilogram-kelvin	...	J/kg·K
stress	pascal	Pa	N/m
thermal conductivity	watt per metre-kelvin	...	W/m·K
velocity	metre per second	...	m/s
viscosity, dynamic	pascal-second	...	Pa·s
viscosity, kinematic	square metre per second	...	m/s
voltage	volt	V	W/A
volume	cubic metre	...	m
wavenumber	reciprocal metre	...	(wave)/m
work	joule	J	N·m

SI PREFIXES:

Multiplication Factors	Prefix	SI Symbol
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto*	h
10 = 10^{1}	deka*	da
0.1 = 10^{-1}	deci*	d
0.01 = 10^{-2}	centi*	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

* To be avoided where possible.

MISSION

of

Rome Air Development Center

RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

AMERICAN REVOLUTION BICENTENNIAL 1776-1976